A37

The Kent Incorporated Society for
Promoting Experiments in Horticulture

ANNUAL REPORT
1953

EAST MALLING
RESEARCH STATION
Near MAIDSTONE
KENT

1st October, 1952 to 30th September, 1953

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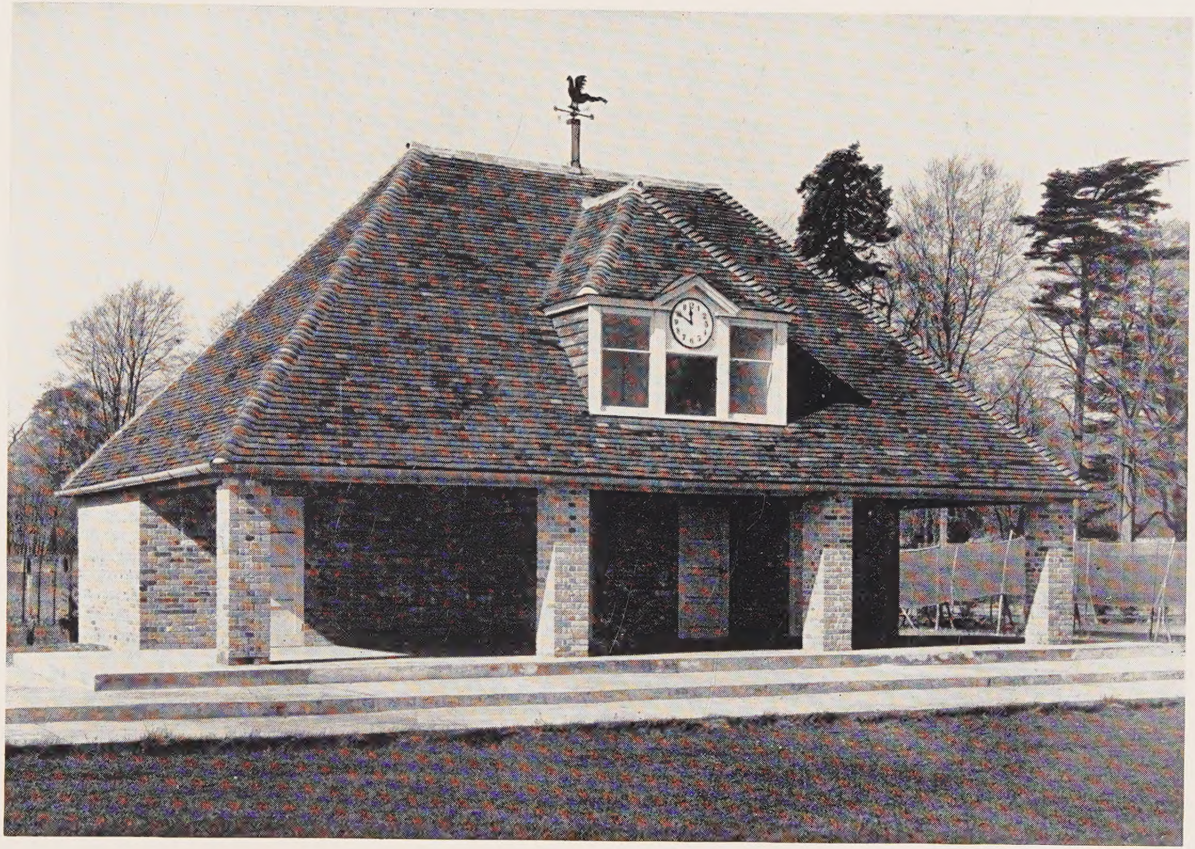

THE SPORTS PAVILION, BRADBOURNE
Built in 1952-53 by the joint efforts of Members and Staff.

[*frontispiece*

A37

THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(FORTY-FIRST YEAR)

1953

EAST MALLING RESEARCH STATION

Near MAIDSTONE
KENT

1st October, 1952 to 30th September, 1953

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The correct abbreviation of the title of this Report is :—
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---

* Recognized Teacher of the University of London.

Plant Physiology—continued.

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Miss M. M. JOYCE. (*Transferred from Pathology Section, March,* 1953.)

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K. W. G. Bunyard. *Laboratory Instrument Mechanic.*

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J. Denyer (33).
E. Wenham (33).
W. Horton (31).
J. Tanner (31).
H. Crittenden (30).
E. Hayes (30) (*Caretaker*).
W. Henson (29) (*Fruit Foreman*).
W. Jenner (27).

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Housekeeper : Miss A. M. Booth. (*Appointed October*, 1952.)

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Tours of the Station are arranged by appointment on Tuesday and Thursday afternoons. Visitors with special interests are received by appointment on the mornings of these days and may then join the general tour later if they wish. Wednesdays and Fridays are reserved for visiting research workers who also should make an appointment to ensure that a useful programme for the visit can be prepared.

All visitors wishing to see the work of the Station should go to the Reception Room in the N.F.U. Building at the Research Laboratories.

Visitors coming by road should take the turning to East Malling, opposite " The Bull ", Larkfield, on the main London-Maidstone road. The entrance gate to the Research Station is on the left, opposite the " King and Queen " in East Malling.

Bus Service : From Maidstone by the Maidstone and District Motor Services Limited, every 20 minutes from Maidstone to East Malling.

Passenger Station : East Malling Halt (British Railways, Southern Region).

Goods Station: Aylesford (British Railways, Southern Region).

Correspondence : All correspondence should be addressed to the East Malling Research Station, near Maidstone, Kent.

Telephone : West Malling 3033 (3 lines). *Telegrams :* Research, East Malling.

THE COMMONWEALTH BUREAU OF HORTICULTURE AND PLANTATION CROPS

Accommodated at Bradbourne, the Administrative Headquarters of the East Malling Research Station.

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Consultant Director : F. R. TUBBS, M.Sc.(Lond.), Ph.D.(Lond.), A.R.C.S., D.I.C., F.L.S.

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Assistants : V. H. GOLDSCHMIDT, Ph.D.(Berlin).
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Miss P. J. ROWE-DUTTON, B.Sc.Hort.(Lond.).
Mrs. E. ULYATT, Dip.Hort.(Eisgrub.).

Clerical Staff : Miss M. B. ROGERS, Miss M. M. DURLING, Miss J. E. MORRISON (*Resigned April*, 1953), Mrs. J. WEBB, Miss M. EDWARDS (*Appointed March*, 1953).

NATIONAL AGRICULTURAL ADVISORY SERVICE

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PROVINCIAL ADVISORY OFFICER—FRUIT, SOUTH-EASTERN PROVINCE

W. G. KENT, N.D.H.

Clerical Assistant : Mrs. J. E. WALDREN.

VIRUS-TESTED MOTHER-TREES FOR THE PRODUCTION OF PROPAGATION MATERIAL FOR WORKING ON TESTED ROOTSTOCKS

In order to facilitate identification, the virus-tested mother-trees made available to Members in 1953-54 will be given the following index numbers :

Early Rivers	M.501
Napoleon Bigarreau	M.502
Merton Heart	M.503
Merton Bigarreau	M.504

LIST OF PAPERS READ AT THE THIRTEENTH INTERNATIONAL HORTICULTURAL CONGRESS, LONDON, 1952, AND PUBLISHED IN THE REPORT OF THE CONGRESS.

Vol. I.

F69	Barlow, H. W. B.	The importance of abscission in fruit production.	Pages 145-52
E370	Beakbane, A. Beryl.	Anatomical structure in relation to rootstock behaviour.	Pages 152-8
E369	Greenham, D. W. P.	Orchard soil management.	Pages 181-9
C307	Harris, R. V.	The maintenance of healthy fruit clones.	Pages 189-98
D257	Massee, A. M.	Fluctuations in orchard fauna.	Pages 250-5
E371	Preston, A. P.	Some new apple rootstocks.	Pages 267-81
E368	Rogers, W. S.	Fruit plant roots and their environment.	Pages 288-92

Vol. II.

E367	Rogers, W. S.	Some aspects of spring frost damage to fruit and its control.	Pages 941-7
E308	Posnette, A. F.	Virus diseases of cacao in West Africa ; the present position.	Pages 1224-30

Note.—These papers were listed, without pagination, under Sectional Reports in Part II of the Annual Report for 1952 (1953).

A. E. BRADFIELD.

[*face p.* 15

A. E. BRADFIELD

Although he was only with us for four and a half years, the Station suffered a heavy loss by the untimely death of A. E. Bradfield in May, 1953.

Alan Edwin Bradfield was born on 11th January, 1897, at Norwich, where he was educated first at the King Edward VI School and then at the City of Norwich School. After leaving school he was apprenticed to a pharmacist, during which period he attended classes at the Norwich Technical School. During the 1914-18 war he enlisted in the Norfolk Regiment and served with distinction on the Western Front, being awarded the Military Medal and Bar. He was commissioned in the East Lancashire Regiment in 1918.

At the end of the war, Bradfield went to the University College of North Wales, Bangor, and here he was to remain, first as a student and later as a member of staff, for the next twenty years. He graduated in 1922, with first class honours in chemistry, and after three years' postgraduate study, as a result of which he was awarded a Ph.D. degree, joined the staff at Bangor in 1925 as lecturer in chemistry. At East Malling we knew little of his work in that capacity, but Members who attended a particularly inspiring lecture and demonstration which he gave us in November, 1950, obtained a good idea of what his students must have owed to him.

But it was not only as a teacher that he made his mark at Bangor for, under the inspiring influence of the late Professor Kennedy Orton, he set about research investigations, the results of which were set forth in a series of papers on the kinetics and mechanism of organic reactions, mainly published in the *Journal of the Chemical Society* between 1924 and 1929, followed by a further series on the chemistry of sesquiterpene derivatives. These were perhaps his most important contributions to the advancement of science. The latter work was carried out in collaboration with Professor (now Sir John) Simonsen, who succeeded Professor Orton in 1930. He was awarded his D.Sc. degree in 1933.

In 1939, he left Bangor to take up an appointment with the India Tea Association and, until 1948, worked in the laboratories of Messrs. J. Lyons & Co. in London, making invaluable contributions to the chemistry of tea, despite the handicap of war conditions.

In the meantime, various problems had been developing at East Malling that called ever more urgently for the appointment of an organic chemist. There had been indications that the solution to such problems as the susceptibility or resistance of different varieties of *Prunus* to Bacterial Canker (*Pseudomonas mors-prunorum* Wormald) or different apple rootstocks to Woolly Aphid (*Eriosoma lanigerum* (Hsmnn)) might be found by a study of the organic constituents of the plants concerned. But the field was virtually unexplored and, when the post in the Biochemistry Section was eventually sanctioned in 1948, the Station was fortunate to secure the services of a man of Bradfield's calibre and experience to fill it. His terms of reference were of the widest—' to study the organic constituents of fruit plants '—and he had to start right at the beginning. There was no laboratory in the already overcrowded N.F.U. Building, no staff and, indeed, no house for him to live in.

However, in October 1948, he took up residence at the Grange (moving to Fircroft in August, 1949, on the retirement of Sir Ronald Hatton) and, undismayed, started patiently and methodically to prepare the tools for the work he had in mind. He selected two assistants, to whom he later added a third, and set about the conversion of the old kitchen in the E.M.B. Building into a laboratory, in the designing of which he lavished the greatest care ; this was not completed, however, until the end of 1950.

With these small resources a start was made on a systematic examination of the organic compounds present in fruit plants. This chemical work was a necessary preliminary to any biochemical investigations that were envisaged because, before a study of the changes that take place in a plant, either in health or disease, can be undertaken, it is necessary to know a good deal about the individual substances involved. The target set, which was to identify, isolate and determine the individual compounds present, although high, was in fact essential in order to build a store of fundamental knowledge that would provide the weapons for an attack on the various horticultural problems at East Malling. Although progress in so difficult a task must necessarily be slow, time has already begun to show that such a patient, systematic approach can provide information of great value to the biologist.

For such an undertaking few could have been better equipped than Bradfield. Many years of pioneer work in the most difficult fields of chemical study had resulted in a vast experience not only of the science of chemistry, but also of logic and scientific method, and the art of teamwork. He brought to bear all he had learnt during his outstanding work on the tea catechins to a qualitative and quantitative study of the complex mixture of water-soluble compounds in the fruit tree, methodically breaking the mixture down into simpler parts and then examining each part in detail. This work, which laid the foundation on which further progress could be built and pointed the way ahead, is to be found recorded in his publications whilst at East Malling.

At the same time as these fundamental studies were pushed forward a start was made on surveying some practical problems of interest to other workers at the Station. This was necessary to ensure that the fundamental work was directed along avenues that would be of greatest help to the pathologist, entomologist, and pomologist. In the course of this aspect of the work there sprang up a very close and friendly collaboration between the organic chemistry team and the biologists, and already at least one of the joint ventures has produced interesting and encouraging results.

In such collaborative work Bradfield excelled. Always ready with a lucid explanation of the chemical problem involved, he was himself eager to understand the biological point of view. Indeed, he was the first to acknowledge his lack of experience of practical horticulture when he came here and, both in his own garden and at the Station, endeavoured to make up the deficiency. Nobody came away from a *tête-à-tête* discussion with him without being infected with his enthusiasm.

Bradfield married Cicely, daughter of the late Mr. John Stribling of King Edward VI Middle School, Norwich, and they had one daughter, who is now studying chemistry at Bristol University, and whom we were glad to have here as a temporary recorder in the Physiology Section last year.

Apart from his more serious work, he was always ready to join in the Station's activities. The Staff Council have good reason to be grateful to him for the sane and level-headed advice and the painstaking work that he contributed as a member of one of their sub-committees. However, he also had an immense sense of humour, and mischief often sparkled beneath his apparently serious eyes ; he had not been here many months before he was adding to the hilarity of our annual Christmas party at Bradbourne.

Those who came into contact with him, either at work or play, never found life dull. His sojourn with us was all too short and we shall not soon forget a well-beloved colleague.

Part I

THE EXPERIMENTAL FARM*

By **F. H. VILLIERS**, with contributions from **T. V. DIXON** and **M. M. MACNEILL**

Growing conditions were on the whole good in 1953, dry open weather in the early spring, the absence of damaging spring frosts, and ample summer rainfall being generally favourable for both top and soft fruit production. However, the summer rains came at just the wrong time for cherry and strawberry growers, causing much splitting and rotting of the fruit. The set of plums and some apples, Cox's Orange Pippin in particular, was disappointing in places, but crops of other fruits were good and prices slightly higher than in the previous season.

Cold east winds in the early part of the year delayed blossoming somewhat and the Myrobalan plums were not in full bloom till almost three weeks later than in 1952 ; picking times, however, varied little from the average. The first Royal Sovereign strawberries were picked on the 9th June, and Early Rivers cherries on 14th June.

Experimental orchards.

Top fruits.

Apples.—The total crop of apples was slightly less than in 1952, 11,426 bushels (40 lb. to a bushel) as compared with 12,964 ; fruit colour and to some extent fruit size were not so good. Apart from Worcester Pearmain, of which we had our heaviest crop since 1948, most other dessert varieties gave slightly smaller yields. The total crop of Cox's Orange Pippin was only just over one-third of that of the previous season and was the smallest since 1944, a frost year. Cooking varieties, on the other hand, cropped more heavily than for several years past. Bramley's Seedling yielded 2,560 bushels, the most since the 4-acre plantation on Kiln Field was grubbed in the autumn of 1949. Fruit size in this variety, unsatisfactory for some years, was very poor in 1953 in spite of hard pruning and heavy dressings of sulphate of ammonia ; in addition the trees themselves made poor growth. The crop of Lane's Prince Albert, on the other hand, was particularly good, and the size and quality of the fruit excellent. The main rootstock trial of this variety in Great East Plantation, now 33 years old, yielded an average of 4½ bushels per tree. There is no apparent falling off in vigour of these trees, which is particularly interesting when it is remembered that, at the time of planting, both ' Paradise ' rootstocks and the scion variety were supposed to be short lived.

Pears.—The crop of pears, though not heavy, shows a slight increase as our younger plantings begin to crop. The total yield was 673 bushels (48 lb. to a bushel). Poor weather conditions at blossom time led to a large proportion of seedless and poorly shaped Conference pears.

The new trial of clonal pear rootstocks on Deadman Field averaged 26 lb. of fruit per tree, the varieties being Williams' Bon Chrétien with Conference pollinators planted as three-year-olds in 1950. Although they did not make much growth in the first season they have since grown strongly.

Cherries.—In spite of the previous season's heavy crops, prospects in the early part of the year were good, but after heavy rains at picking time a large proportion of the fruit split and rotted. The Early Rivers were largely picked in dry weather, a total of 499 halves (24 lb. to a half sieve) being marketed. On the other hand Bigarreau de Schrecken, a variety inclined to split, was completely ruined and, although 186 halves were picked for recording purposes, only 30 halves were fit to send to market. The same is true, to a lesser extent, of our other main variety, Turkey Heart, only 233 halves being marketed as against 908 halves in 1952.

Plums.—After the glut of 1952, 1953 was a year of light plum crops in most parts of the country. Although at East Malling Victoria and Bountiful required thinning, most varieties gave only moderate yields. The total quantity marketed was 1,744 halves (28 lb. to a half sieve) as against 3,054 halves in 1952 ; part of the difference, however, is due to the grubbing of 1½ acres of mature Victorias in the early spring. Among the gage plums in the variety collection only Oullins Golden Gage, Cambridge Gage, and Denniston's Superb gave worth-while crops ; as with the cherries, there was much splitting.

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* For the calendar year 1953.

The plum Ontario, planted amongst the gages, once again demonstrated its regular cropping habit and yielded only slightly less than in the exceptional plum year of 1952.

Peaches.—The wall peaches in Bradbourne Gardens again cropped heavily and yielded over 4,000 fruits ; the bush trees, however, were disappointing, yielding very little after last year's appreciable crop.

Soft fruits.

The only black currants now remaining are ½ acre of Goliath on Newgates Field and one or two small beds for laboratory trials. The total crop from all sources was approximately 15 cwt.

The raspberry crop was again satisfactory, though not so heavy as in 1952, being only about 5 tons, as compared with 8 tons in that year. Our plantations have now mostly carried seven crops and some of the less satisfactory seedlings are failing to produce sufficient cane to furnish the wires ; Malling Enterprise is particularly bad in this respect. High winds did considerable mechanical damage to the fruit and further losses resulted from *Botrytis* infection following heavy rain.

Dull humid conditions and wet weather up to picking time also resulted in much rotting in the early varieties of strawberries, particularly Royal Sovereign, on some plots 50 per cent of the fruit being attacked by *Botrytis.* Removal of affected fruits had little influence on the spread of the disease, but, as soon as the weather improved, good crops of Climax and other late varieties were gathered.

Loganberries were disappointing ; the canes lack vigour and, in spite of generous applications of dung and artificials, made very poor growth. In consequence the crop was light—just over 1 ton from 1·3 acres. Rubus Stunt again infected several plants which were removed. It is interesting to note that this disease has so far been confined to the thorned plants, none of the thornless having shown recognizable symptoms so far, although there are twice as many in the trial.

Fruit marketing.

As was general in this district, fruit colour and, to a certain extent, fruit size, was not as good as in 1952, the fruit of most dessert varieties lacking the exceptional brightness and finish of the previous season. A determined effort was made to improve the fruit size of all dessert varieties this year. Most of the trees of Worcester Pearmain were severely spur thinned at pruning time ; the fruit was later thinned to a single fruit to each blossom truss. Duchess' Favourite and Beauty of Bath were also singled, and Allington Pippin and Miller's Seedling fruits spaced from 6 to 8 inches apart where experimental considerations allowed. Fruit size was improved by these treatments but not as much as had been hoped ; it seems that in many cases fruit must be spaced to give any real results.

With cooking varieties the treatment applied was more drastic. In addition to hard pruning, the fruits of Early Victoria, Lord Derby, and Grenadier were spaced to 1 foot apart and those of Lane's Prince Albert to 8 inches as early in the season as the fruit could be handled. Results were most satisfactory and good samples of early cookers were marketed early in the season at remunerative prices. The fruits of Bramley's Seedling, on the other hand, which it was not possible to thin, were disappointingly small.

All fancy grade dessert apples were marketed in half bushel non-returnable cardboard containers, the larger sizes of most varieties, 2½ in. in diameter and upwards, making satisfactory prices. In the case of Worcester Pearmain, however, prices soon dropped for even the best samples, and 1,700 bushels of this variety were put into gas store in the hope that they would meet a better trade later on ; this expectation was realized, especially as regards the smaller fruit. A second store was filled with Lane's Prince Albert and Bramley's Seedling for gas storage until the new year, and our third store with Cox, Laxton's Superb, Allington, and other of the later keeping varieties for cold storage until Christmas.

The lighter plum crop made marketing easier this year. The majority of our plums and gages were graded and marketed in 12-lb. chips and sold well. Cherries also sold well but the improvement in price over last year was largely offset by the greatly increased cost of sorting the badly split crop. All the soft fruit was sold for processing, as the handling involved in taking experimental records impairs appearance for market purposes.

Fresh plantings and grubbings.

In the autumn of 1953 two new cherry trials were planted. One, planned to assess the importance of some of the cherry viruses, occupies approximately 1½ acres on Church Fields (C5) adjacent to the existing cherry trial, and the other, a trial of different methods of tree-building, is on Newgates Field (N1). A third of an acre of black currants for a virus trial and ¼ acre of plum rootstocks for the

Physiology Section were also planted in Newgates (N4 and N3 respectively). About 2 acres of mixed fruit trees and bushes for spray damage trials on part of Park Farm (P12) and a small area of apples adjacent to the laboratories (E20), again for the Physiology Section, completed the planting for 1953.

Areas grubbed include the remainder of the cherry variety collection on Egham Field (E29 and E35) and the interplanted apples on M.IX (E35), the frameworked Cox and Worcesters on a strip of Kiln Field (K6), the adjacent Charles Ross (K5), and the Duchess' Favourite in the manurial trial on Church Fields (C2). The collection of late flowering and dessert apples on Egham Field (E33) are also to be cleared, the best of these having been established elsewhere. Work on the Black Currant Midge spray trial in Newgates Field is now completed and the ½ acre of Goliath planted for this purpose will also be cleared.

Routine spray programme.

Last year's policy of reducing the use of winter washes was continued in 1953. No tar oil was used on cherries, pears, or black currants, and only the younger apple plantations and laboratory trials were sprayed with DNC. Aphids and caterpillar were quite satisfactorily controlled on apples and pears by the addition of DDT emulsion to the Scab spray at bud burst.

Peaches, loganberries, and raspberries were sprayed with 5 per cent tar oil before Christmas, and plums with 3 per cent DNC during the latter half of February. An emulsion DNC, containing 95 per cent oil and 3·3 per cent DNC, was again used and gave very satisfactory results.

The wet summer made Scab control difficult, but, by following closely the timing given in the 1949 edition of the ' Spray Calendar ', good commercial control was achieved. All varieties of apples received three pre-blossom lime-sulphur sprays at strengths of 2½ per cent, 2 per cent, and 1½ per cent at the bud burst, green cluster, and pink bud stages respectively. Post-blossom, Cox received three dispersible sulphur sprays, and other varieties two of lime-sulphur and one of mercurated lead arsenate. Apple Sawfly infestations did not appear to justify special measures ; later, however, some damage was evident, and it will probably be necessary to spray against Sawfly next year. Two and a half pints of DPS (35 per cent suspension) and ¾ pint of liquid derris were added to the fruitlet stage Scab spray and to the end of June Codling spray, against Red Spider. Results, however, were variable, both in plantations which had been winter washed and in those which had not. All plantations received two lead arsenate sprays against Codling Moth, though attacks by this pest were not so severe as in 1950 or 1951.

The pear plantations received two pre-blossom lime-sulphur sprays, to the first of which DDT emulsion was added for the control of aphids. Post-blossom, plantations containing the variety Doyenné du Comice were sprayed twice with a mixture of lead arsenate and dispersible sulphur, and other plantations twice with mercurated lead arsenate.

Cherries were sprayed with Bordeaux mixture at 10.15.100 in October and again at 6.9.100 at white bud. Our young plum plantations were sprayed with Bordeaux at 4.6.100 at three weeks, and again at six weeks after petal fall for the control of bacteriosis ; Czar plums and damsons were, in addition, sprayed with derris at the ' cot-split ' stage against Plum Sawfly.

As last year, raspberries were sprayed twice only—once with BHC against Cane Midge in early May and once with derris at the pink fruit stage against Raspberry Beetle. There has been little trouble with Cane Spot amongst either raspberries or loganberries ; the latter were, however, sprayed twice against Cane Spot as well as twice against Raspberry Beetle. Strawberries were sprayed against aphids and dusted against Mildew and Strawberry Blossom Weevil.

Arable crops.

The area under arable crops was slightly less in 1953, 119 acres as against 126 acres the previous year. Growing conditions throughout the summer were good and yields were satisfactory.

Potatoes.—These gave excellent crops. In addition to 5 acres of Stourmont Dawn and 7½ acres of Majestic, 5 acres of the variety Dr. Mackintosh were grown. This is a fairly recent introduction ; it is a heavy cropping, early main crop variety, and cooks excellently. Our crop is not yet marketed but looked very satisfactory at lifting time.

Peas.—The abundant summer rainfall suited our canning peas, which cropped more heavily than for some years. 7 acres of Surprise averaged 30 cwt. of shelled peas per acre and 9 acres of Lincolns nearly 2 tons. A Leverton pea cutter was used to harvest the Lincolns and saved much labour, but was rather unreliable.

Cereals.—26 acres of wheat, 18½ acres of barley, and 4½ acres of oats were grown ; although the barley was badly lodged, it was harvested in reasonable condition. The only wheat so far threshed, Eclipse, averaged 7½ qrs. per acre, while Sun II oats averaged 9 qrs. Hay and silage were made from our 22½ acres of one-year ley. The weather was not good for harvesting ; this sort of season emphasizes the advantages of silage making. In addition to our usual crops, 9 acres in Ditton Fields were sown after harvest with S.37 cocksfoot which will be harvested for seed. Prior to the wheat crop just taken, this field was occupied by stoolbeds for 10 years and it is hoped that the mass of roots produced by the cocksfoot will, when finally ploughed in, help to restore the organic matter content of the soil and improve the soil texture.

Thirty-four Devon steers were yarded for the winter. As our acreage of cereals is now considerably reduced, an extra 100 tons of straw will be bought.

F.H.V.

Experimental nurseries.

The 1953 distribution of trees and other nursery material has been the most important for several years. The dry open weather in the autumn favoured lifting operations, and most of the material had been lifted and despatched by the end of January.

Some 110,000 of the new apple rootstocks, MM.104, MM.106, MM.109, MM.111, and M.XXV were raised, as well as 8,000 M.II, 8,000 M.VII, and 4,000 Crab C.

Some of the new apple rootstocks transplanted well. Of the material bedded in during the winter of 1952-53 it is estimated that 6 to 8 out of every 10 were fit for distribution ; MM.106 seems particularly good in this respect. Some of these rootstocks grew so well that they were rather too large for budding purposes ; this was especially so with MM.106, and to some extent with MM.111.

A number of sets of the new rootstocks have been taken up by Members and education authorities to be used for identification purposes. This is thought to be a good thing, for they are not easily distinguishable. MM.106 and M.XXV can be fairly easily recognized, but MM.104, MM.109, and MM.111 are more difficult.

For the first time trees of scion varieties, tested for their freedom from virus, were distributed for use as ‘ mother trees ’. The only ones sent out this year were the four cherry varieties, Merton Heart, Merton Bigarreau, Early Rivers, and Napoleon, but it is hoped that other varieties will be available next year. The F12/1 cherry rootstocks distributed were also virus free and should thus allow of the building up of virus-free trees of the cherry varieties mentioned.

The trees and graft wood of the apple variety Michaelmas Red which were distributed come from virus-tested ‘ mother trees ’.

Two thousand two-year-old black currant bushes and 4,000 cuttings were also raised.

In the nursery the testing of rootstocks and experimental trees for virus has continued, and a further 15,000 buds were placed during the summer.

A very considerable number of trees and soft fruit bushes are being raised for N.A.A.S. Experimental Horticulture Stations, for example, 1,250 trees for one Station, and 150 trees and 700 black currant bushes for another.

Sets of maiden trees on the five new Malling-Merton apple rootstocks, with four of the Malling rootstocks as controls, have been raised for planting at different centres, so as to obtain information on the performance of trees on these new rootstocks under different climatic and soil conditions.

T.V.D.

Experimental glasshouses.

During the year many alterations and additions have been made in the glasshouse area, several to provide increased facilities for fruit breeding. The compartment at the south end of the orchard house has been made more suitable for fruit tree pollination work. A new Dutch light house, 40 feet long and 13 feet wide, in which much of the glass is replaced by wire gauze, has been erected in the same area, in order that small nuclei of new raspberry varieties may be kept virus-free in the same way as has been done for many years with the special stocks of strawberries. Further steam-heated frames have recently been constructed to accommodate the 8,000-9,000 seedlings which will be raised annually as part of the apple breeding programme.

During the winter of 1952-53 a small number of apple and pear trees, and tomato and strawberry plants were kept in a heated and artificially lighted greenhouse to extend the growing season. As a result of these small-scale tests it was decided to adapt one of the ‘ dedutchable ’ houses by erecting a smaller house inside it, thus reducing the area to be heated and also the heat loss from the inner house. A high pressure mercury vapour and tungsten light unit was found to be the best source of illumination ; leaf colour tended to be a darker green under these lamps than under fluorescent lighting.

Eight concrete bays, each large enough to take sixteen 12-in. pots, have been built for experiments with Verticillium Wilt of hops, and further efforts have been made to reduce temperatures in the new virus houses during hot spells by alterations to the ventilating system and the provision of more lath and scrim blinds. To enable the staff to cope with the ever-increasing numbers of plants in pots, now nearly 13,000, two concrete benches, 12 ft. by 2 ft. 6 in. by 3 in. deep, in the new virus houses have been adapted so that they can be watered by simply turning on a tap ; this method has been fairly satisfactory.

It is well known that certain seeds which require a cold spell before they germinate do not, in some cases, germinate until a second cold spell has been experienced, i.e. until they have lain dormant for two winters. To save a year, a number of apple, pear, peach, plum, and gooseberry seeds, which germinated poorly after the natural cold spell during the winter of 1952-53, were subjected to a second, artificial cold spell in April and May 1953. The seeds were kept for periods varying from 34 to 69 days at between 32° F. and 34° F. ; both treatments were successful in the case of apple and gooseberry seeds, but none of the pear and plum seeds, and only a few of the peach seeds, responded. It seems important that the seeds should be kept moist while under this treatment ; apple seeds kept dry at a similar temperature germinated very irregularly.

In order to ensure that pollen of the variety Cox's Orange Pippin was available for pollination work with that of varieties not normally flowering until much later, some 70 trees of Cox in pots were kept in cold store from February till the third week in May at a temperature of 38° F. to 42° F. When these trees were transferred to a greenhouse the blossoms opened satisfactorily at the required time.

The cultural trials on potted trees, mentioned in last year's Annual Report, were continued, and a way has now been found to mitigate the adverse effects of the severe root and branch pruning to which trees, which have become established outside, are subjected when first potted up.

M.M.M.

Part II

GENERAL REVIEW OF RESEARCH WORK

WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

By W. S. ROGERS

Work in the laboratory and the field has made good progress. Among interesting new developments, studies of fundamental aspects of irrigation and soil moisture control have been expanded, a promising correlation between apple stem structure and resistance to Woolly Aphid has been found, and further progress has been made with filming the process of freezing plant tissues under the microscope.

Publications are listed on page 29 ; in addition, four members of the Section have helped to prepare a Glossary of terms used in pruning, for the Horticultural Education Association.

Tree fruits.

Few major changes have been made in the tree fruit trials ; only a few of the items of interest can be described in this report.

Rootstocks.

The classical rootstock trial of Lane's Prince Albert apple, now 34 years old, has responded well to spur-thinning and spur-shortening, and bore good-sized fruit. The young trees of Jonathan, on the Malling-Merton series of rootstocks, now in their ninth year, bore their sixth successive good crop ; but the Cox trees in the same trial only bore lightly, in contrast with the preceding year. Several papers on the Malling-Merton rootstocks were published (E373, E374, E379, E385).

The trial of pears on clonal seedling quince rootstocks has reached a stage when a further selection, mainly of dwarfing types, can be made.

The gage plum rootstock trial, now 13 years old, has given interesting results. While in general trees on the most vigorous rootstocks have carried the heaviest crops, Oullins Golden Gage has so far cropped most heavily on Common Plum, the rootstock giving the smallest trees. Differences are already appearing in the trial of semi-dwarfing rootstocks, now 7 years old. Ackermann's has proved the least satisfactory rootstock so far ; trees on it have borne the lightest crops and have suffered most from bacterial canker. A new trial of semi-dwarfing rootstocks, containing Cambridge Gage and Rivers' Early Prolific on Marianna, St. Julien A and K, Ackermann's, Pershore, Michaelmas Prune, and a new seedling raised here (E.33/4), has been planted.

A report on the conclusion of an investigation into the reinvigoration of unthrifty apple trees by the inarching of vigorous rootstocks has been prepared.

Incompatibility.

Trees of three plum rootstocks grafted together in all combinations have grown well. The graft unions will be examined during the winter of 1953/54 to determine the degree of disturbance of tissues in unions between different rootstocks compared with those between parts of the same clone.

Records have been continued on trials of plum and pear trees designed for a study of the anatomy of several graft combinations differing in their degree of compatibility. Five new plum rootstocks are being propagated, and have been budded for compatibility tests. The Kentish cherry, commonly used as a rootstock in Australia, has been worked with a range of virus-tested cherry varieties. Eighteen apple rootstocks have been budded with pears for a study of differential preference. A paper on double working pears at budding time has been published (E381).

Histology.

In collaboration with the Entomology Section, a study has been made of the relationship between the structure of the phelloderm of stems of young apple seedlings and resistance to colonization by Woolly Aphid. In the autumn of 1952, seedlings from the cross Northern Spy × Laxton's Superb were examined together with suitable control plants. A close relationship was found between cell shape and cell wall thickness in the phelloderm, and resistance to Woolly Aphid. During the summer of 1953, the development of the phelloderm was studied in sections prepared every month from May to October in seedlings from the cross Northern Spy × Cox's Orange Pippin. The development of the phelloderm was also examined in the region of the hypocotyl and of the stem bases of seedlings from various apple varieties. Examination of other families of seedlings and of resistant and susceptible varieties from East Malling and Wisley is not yet complete, but there is some indication that a similar relationship may be found in them.

The structure of young stems in relation to ease of vegetative propagation has been studied in the Malling-Merton apple rootstocks and in families of seedlings from the plum variety Pershore. There was evidence of a relationship between the structure of the tissues between the cortex and the secondary phloem and ease of rooting from stems, the relationship being especially clear in the Malling apple rootstocks.

Further studies have been made on the connection between root structure and rootstock effect, both in the Malling and Malling-Merton apple rootstocks and in certain plum rootstocks. Scion effect on rootstock structure has also been examined in the Malling apple series.

The study of phloem structure in stems of apple varieties and its relation to the underlying rootstock has been continued. Preliminary results indicate that the relative amounts of storage and conducting tissues in the phloem may be affected by the rootstock.

Apparatus is being developed for the mechanical testing of the strength of apple and plum wood. Preliminary results, comparing the length of fibres from the tissues of one-year-old shoots of plum varieties with strong and with weak branches, with the deflection angle at which breakage occurs, seem promising.

A short paper has been published (E777) on a cambium miner found in the stems of plum trees.

Propagation.

Attempts are being made to provide a wide range of apple scion varieties on their own roots for use in further trials of rootstock effects.

'Easy rooting' apples from Cheshire, Cornwall, Middlesex, and from Chile, 'easy rooting' pears from Australia, Ceylon, France, Holland, and the United States, and a plum (Morrison's), reputed of wide compatibility, from New Zealand have been received for study.

Propagation experiments have been continued jointly with the Physiology Section. As a preliminary to investigating the behaviour of adventitious shoots as cuttings, the initiation of sphaeroblasts on Malling Crab C apple is being studied. Concrete bins have been constructed to provide additional facilities for storage experiments with cuttings. Experiments with apple root cuttings have provided additional information on the effect of source and planting treatment. Apple leaf-bud cutting experiments have continued and a report has been prepared (see page 145).

Double-working.

Two-year trees of Williams' Bon Chrétien pear, double-shield budded on Quince A, have retained their leaves longer than single-worked trees. A paper on this technique has been published (E381). A small-scale double-shield budding trial of apricot on plum has been worked using a peach as intermediate.

Soil management and manuring.

The short-term ley experiment on trees of several apple varieties on M.IX has been concluded.

A further season's records of two soil management trials started in 1951 have shown that Laxton's Superb and Laxton's Fortune trees on M.II have not fully recovered from the check following grassing down in the spring of 1951, five years after planting, with a perennial ryegrass-wild white clover mixture. Final conclusions regarding the relative merits of different types of sward for orchard use cannot yet be drawn, but the severity of the initial check, particularly with Laxton's Superb, suggests that perennial ryegrass, if sown right up to the trees, should be used only for vigorous trees on deep soils in areas of at least moderate rainfall. At this early stage S.50 timothy appears promising as an alternative providing less vigorous growth, greater ease of management and less severe initial competition with the trees. Information regarding its long-term effects is not yet available. Meanwhile the most vigorously growing trees in these trials are still those in the permanent straw mulch treatment, suggesting that the use of a mulch round the trees, for an initial period, in young orchards that are grassed down may have valuable practical advantages.

In the factorial NPK trial, now twenty-two years old, several important changes have been made. The remaining trees on M.I and M.V were removed, leaving only one tree of Cox's Orange Pippin on M.XII in each of the 64 plots, surrounded in each case by a double guard alley of trees on M.IX. In the spring a further factor, grass *versus* cultivation, was superimposed on the trial. This was done both to study the interactions between the effects of grassing down and those of N, P and K on tree nutrition, growth, and cropping, and to provide fruit of Cox's Orange Pippin from a wide range of cultural treatments for storage investigations (see page 50). The mixture sown was the standard used in other trials, 16 lb. per acre S.23 perennial ryegrass with 2 lb. per acre Kent wild white clover. Interesting observations have been made on the establishment of these swards, particularly as regards clover content, under different fertilizer treatments. Effects of the swards on the leaf colour of the trees and on fruit colour have already been noted. Meanwhile, since the previous rate of application of nitrogen on the N plots (sulphate of ammonia at 3 cwt. per acre per annum) would not be regarded as adequate for trees in grass, it was decided to double this application from 1953 onwards and, to give a better chance of showing potash effects, to discontinue from 1954 the overall dressing of 2 cwt. per acre per annum of sulphate of potash which has been superimposed on the whole trial since 1937 and to revert to the original treatments involving a comparison of 2 cwt. per acre per annum sulphate of potash with no potash. At this important ' milestone ' in the history of the trial, soil samples have been taken and pH, and available phosphate, potash and magnesium in 6-in. zones to a depth of 36 in. on each plot, have been determined, with the helpful assistance of the N.A.A.S. soil chemists. Leaf samples were taken by the Biochemistry Section, who have also continued to collaborate by sampling and analysing leaves from several of the other trials already mentioned (see page 34).

Soil studies.

The studies of the soil moisture conditions under different soil management practices have been continued, and now include two new irrigation trials. Work has also continued on the trend of change of organic matter content in the soil under different orchard management practices. By means of a mechanical wet sieving technique the water stability of soil crumbs from plots, under permanent grass, clean cultivation and treated with a ' soil conditioner ' has been estimated. The grassed and the ' conditioned ' soils have a much higher percentage of water stable aggregates in the surface layer than has the untreated clean cultivated soil (see also page 123).

The detailed soil survey of the Research Station by Mr. B. S. Furneaux has been completed and an account of the survey appears on page 60.

Irrigation.

Two new irrigation trials have been started on eight-year-old apple trees on Larkfield plantation. In the first, on Laxton's Superb on M.II, the soil moisture conditions are being controlled within limits from April to September inclusive by irrigating when the soil moisture tension at one foot depth has reached, respectively, values of 10 cm., 20 cm., and 50 cm. of mercury ; the control plots receive only the natural rainfall. This trial receives sulphate of ammonia at the rate of 6 cwt. per acre.

The second trial, on Laxton's Fortune on M.II, is a study of the interaction of nitrogen and water supplies on growth and cropping. The treatments consist of irrigation at 20 cm. tension, and no irrigation, both at two levels of nitrogen, viz. 6 cwt. per acre and 3 cwt. per acre of sulphate of ammonia.

Irrigation is applied by the basin method. Intensive serial records of shoot growth, trunk swelling, and fruit size increase are being made. A Growers' Bulletin on irrigation has been published (E380).

Restoration of soil uniformity.

The trial of restoration of soil uniformity following the grubbing of an old plantation has continued, in collaboration with the Statistics Section. Indicator plants of M.VII rootstocks were planted on half the area, and they have now been budded with the varieties Cox's Orange Pippin and Tydeman's Late Orange.

Root studies.

Root development of apple trees under a 10-year-old grass sward and under clean cultivation was compared by excavating whole trees and by taking root samples. Differences were found in root spread and in vertical distribution.

Pruning.

The apple pruning trials, now in their eighth year from planting, have shown interesting results. The regulated method of pruning appears to be useful for bringing filler trees into early and heavy bearing, but further work is necessary before the method can be confidently recommended for use with permanent trees. Preliminary reports have been prepared (see pages 105 and 200).

In the 5-year-old plum pruning trial, much heavier crops were carried by the unpruned than by the pruned trees. In spite of the wider branch angles in the unpruned trees, they suffered more severely from branch breakages because of the heavier crops.

In the bush peach pruning trial, trees of one variety, Bellegarde, have been severely damaged by Bacterial Canker and some winter-pruned trees have shown symptoms of Silver Leaf during the year.

Fruit thinning.

A paper covering a seven year fruit thinning trial on Duchess' Favourite trees on M.IX has been prepared. An effect of thinning on regularity of cropping persisted for two seasons after the completion of the trial.

Biennial bearing.

Studies of the life histories of spurs of regular and biennial varieties of apple, and of the effects of defoliation on fruit bud differentiation, together with further results of bud rubbing and blossom thinning, are being summarized for publication. Further experiments were carried out in 1953 with defoliating sprays, using off-year trees of Laxton's Superb in growers' plantations.

Breeding.

Attempts to produce improved rootstocks for pears from hybrids between the pear and the quince have been continued. The existing hybrid, *Pryonia veitchii luxemburgiana* is being back-crossed to pear.

A number of *Prunus* species likely to make useful parents for a programme of cherry rootstock breeding have been collected.

The late-flowering apple varieties Blanc Sur, Court Pendu Plat, Cravert Rouge, and Crawley Beauty, chosen from a number of late flowerers collected from Wisley and elsewhere with the valuable assistance of the National Fruit Trials, were crossed with Cox's Orange Pippin with the ultimate object of producing seedlings combining late flowering with desirable fruit quality. Cox's Orange Pippin, Court Pendu Plat, and Crawley Beauty were also selfed to provide possible parents for use at a later stage in what must be a long-term programme. From about 26,000 pollinations more than 8,000 seeds were obtained.

In collaboration with the Entomology Section, work has been continued on the raising, testing, and selection of seedlings combining a high degree of resistance to the Woolly Aphid with desirable fruit characters.

Selection work is also proceeding among a number of apple and pear seedlings from earlier crosses.

Varieties and classification.

The apple variety trials, which include Tydeman's Early Worcester, Harvest, Michaelmas Red, Martinmas, October Pippin, and Tydeman's Late Orange, together with established varieties of comparable season, are coming into full cropping. Harvest has so far cropped much more heavily than Beauty of Bath, but it ripens about a week later. It has been decided that the further testing of Martinmas and October Pippin is unwarranted and these seedlings, which have not been released, will not be further propagated. Anyone having a trial tree or trees of either of these is requested to framework the trees with some other variety. The gage and plum variety collection has been maintained.

Small fruits.

Variety and strain trials.

Strawberries.—Botrytis rot took heavy toll of early varieties, including Cambridge Forerunner, Profusion, and Early Pine, which were cropping for the second time. In the same trial Cambridge Premier cropped as heavily as Huxley. In the three-year-old trial Climax was still the heaviest cropper at 5¾ tons per acre. A short paper on strawberry varieties was published (E382).

In a trial of Climax runners from normal parents, parents with ' transient yellows ', and parents with ' streak ', there were marked differences in vigour, crop, and runner production in the first year, suggesting that careful selection can at least partly mitigate this trouble.

Raspberries.—Like the strawberries, the raspberries were badly affected by *Botrytis* rotting of the fruit, yields being far below the heavy crops of 1952. The early ripening varieties, including Malling Exploit and Malling Promise, were more severely attacked. The cropping trials bore their seventh and fifth crops respectively ; the order of cropping was abnormal, presumably owing to the unequal incidence of *Botrytis* on the fruit.

Loganberries.—The cane growth of plants in a loganberry training and variety trial has been poor in spite of generous manuring and good cultural treatment. The Malling clone of the thorned Loganberry produced more cane and a heavier crop than the thornless. A search is being made for better clones.

Breeding.

Raspberries.—Seeds of six further families have germinated in 1953. Of these, only two are of red raspberry—Malling Exploit selfed and Baumforth B selfed ; the latter is already of interest in confirming an observation of thirty years ago, that Baumforth B produces sex forms when selfed. Two other families are F2 generations from ' purple ' hybrids (*R. occidentalis* × *R. idaeus*), raised for further observations on the absence of segregation in such families. One family is a repetition of the cross of Boysenberry with Malling Exploit, mentioned in the 1952 Report (page 25) ; the last is Lloyd George pollinated by *Rubus palmatus*, an Eastern species ripening its fruit in May.

The family mentioned in the 1952 Report, raised from a cross of two exceptionally good self-pollinated red raspberry seedlings, has begun to fruit and looks promising for fruit quality, but the canes are surprisingly lacking in vigour. Several further selections, designed mainly for further breeding, have been made from the families germinated in 1950.

Black currants.—Crosses were made between black currant varieties and several nearly related *Ribes* species, and the resulting hybrids are being treated with colchicine to induce tetraploidy. Artificially-induced tetraploid forms of black currants are being studied, intercrossed, and back-crossed with a view to the production of forms with differing chromosome numbers.

Gooseberries.—A collection of gooseberry varieties with much reduced spines, but of inferior fruit size and quality, received from Canada, have been intercrossed with Lancashire Lad. Selection will be made among the seedlings as the first step in a programme directed towards the combination of good fruit size and heavy cropping with reduced spininess.

Cultural measures.

Strawberries.—In the four-year-old cultural trial of Climax the best treatment, matted rows which had been burnt after the previous crop, cropped at the rate of 7 tons per acre of marketable fruit. The cropping rate of a three-year-old Royal Sovereign trial, comparing modified matted rows and beds, ranged from 4 to 4½ tons per acre of marketable fruit in spite of considerable losses from *Botrytis*. On a cultural trial of Sovereign and Climax, including manurial and irrigation treatments, the Plant Protective Chemistry and Plant Pathology Sections collaborated in testing a new chemical as an anti-*Botrytis* spray.

Raspberries.—The favourable results given by a straw mulch, compared with clean cultivation, during the previous two years were not maintained at the same level in 1953, owing to a serious loss of cane in the spring. The cause of the cane death, which was more serious in the mulched than in the cultivated plots, is as yet undetermined. The mulched plots cropped only slightly better than the cultivated ones in 1953.

Frost damage investigations.

Numerous but light air frosts in the spring of 1953 caused some damage to buds and blossom of most fruits, but reduced the crop in only a few of them. Detailed phenological observations made on many small and top fruit varieties proved most useful in correlating the frost damage with the stage of development and the climatic conditions.

Early April frost killed back some young laterals of the early raspberry varieties such as Malling Exploit and Malling Promise ; these were as a rule replaced by secondary shoots. Records were made of the time of blossoming, fruit ripening, and total crop of primary and secondary laterals on the same canes.

The petals of certain apple and pear varieties in the Bradbourne Gardens were badly damaged by frost. However, such injury, except when accompanied by discoloration of styles, does not affect the fruit set and, in fact, good crops were harvested from many of these varieties. Buds and blossoms of Bramley's Seedling were thinned by frost at various stages of development, mainly at the green cluster stage, but without much effect on final crop.

This year 39 of the 195 apple seedlings, bred for selection of plants differing widely in their frost resistance, began flowering. Detailed observations were made of their time of blossoming and frost damage.

Temperatures were recorded in various parts of the frost plot compared with those in Bradbourne gardens. Differences were small, in average not exceeding 0·3° C. (0·5° F.).

Three water sprinkling experiments were carried out in a mature apple orchard for protection of blossom from frost damage. The air temperature, however, did not fall low enough to show the effect of the treatment. Wind records were taken at various heights and positions among the trees with a special set of recording anemometers kindly loaned by Dr. H. L. Penman, of Rothamsted Experimental Station. A 6-point Cambridge quick acting recorder, intended for recording blossom temperatures in the orchard, has been modified to meet experimental requirements.

Two experiments were carried out to determine the effect of cultivating and of rolling the soil upon the air temperature at various heights above the surface.

Laboratory experiments on frost resistance of five apple varieties (Bramley's Seedling, Cox's Orange Pippin, Ellison's Orange, Ribston Pippin, and Worcester Pearmain) were supplemented with a study of the water content and the relative rate of water loss from the buds, flowers, and fruitlets under drying conditions. In connection with these investigations a histological study is being made on buds, flowers, and fruitlets of Bramley's Seedling and Ribston Pippin to determine the course of damage and to correlate it with the anatomical structure and development of various tissues.

Ten apple varieties grown in pots were tested for their relative resistance to frost and for their ability to set fruit from flowers which had suffered varying amounts of frost damage. A preliminary test of frost resistance of 21 apple seedlings was carried out on cut flowers. Differences in the kind and amount of frost damage were observed. The relative frost resistance of Frogmore and Roundel cherries was studied at three stages of floral development and their ability to set fruit following frost was recorded. Some preliminary freezing tests were also made on gooseberry plants grown in pots.

The effect of eleven different substances, including growth inhibitors and plasmolisers, applied to apple blossom before frost was further investigated.

The processes of freezing plant tissues under the microscope were further studied, mainly on leaves of the moss *Pherygophyllum lucens*, kindly provided by Dr. L. I. Scott of Leeds University. The processes investigated included the freezing and longitudinal splitting of cell walls, the mode and rate of ice formation as affected by supercooling, and freezing of living and dead cells.

Three papers, on frost resistance of black currant varieties (E375), on 'washing off' of hoar frost (E376), and on improvements in thermocouples (E372) were published.

Mycorrhiza.

The results of seven years of work on mycorrhizal infection in fruit plants, particularly apples and strawberry, are being written up. A note has been published on mycorrhizal fructifications associated with strawberries (E384). Inoculation experiments with the fructifications and with spores excised from them have been successful, although inoculation with mycelium cultured from the spores has not given typical infections. The fructifications associated with strawberry plants have produced mycorrhiza in apples and other plants. Preliminary observations have been made on the growth of mycorrhizal and non-mycorrhizal apple seedlings and strawberry runners grown in pots in a greenhouse. Following up these observations a pilot trial has been set up with strawberries grown in autoclaved soil in galvanized iron drums out of doors.

Walnuts.

Crops were not heavy this year and, because of the poor weather conditions, many of the nuts had imperfect shells.

Horticultural meteorology.

Routine meteorological observations and special records of air temperature, soil moisture, and wind in relation to various experiments have been maintained. Observations at the sub-station at Throwley have continued. The Meteorological Office has again kindly supplied special frost warnings for our frost investigations.

Publications During the Year.

E372 Slater, C. H. W. **Improvements in fine wire thermocouples.** J. sci. Instrum., 1953, **30**, 293-4.

E373 Tydeman, H. M. **A description and classification of the Malling-Merton and Malling XXV apple rootstocks.** Rep. E. Malling Res. Sta. for 1952 (1953), 55-63.

E374 Garner, R. J. **The nursery behaviour of the Malling-Merton and Malling XXV apple rootstocks.** Rep. E. Malling Res. Sta. for 1952 (1953), 64-6.

E375 Modlibowska, Irena and Ruxton, J. P. **Preliminary studies of spring frost resistance of black currant varieties.** Rep. E. Malling Res. Sta. for 1952 (1953), 67-72.

E376 Modlibowska, Irena. **Some experiments on ' washing off ' the hoar frost.** Rep. E. Malling Res. Sta. for 1952 (1953), 73-7.

E377 Lee, N. R. **Note on a plum cambium miner (Agromyzidae).** Rep. E. Malling Res. Sta. for 1952 (1953), 78-9.

E378 Preston, A. P. **Weather conditions during 1952.** Rep. E. Malling Res. Sta. for 1952 (1953), 80-2.

E379 ——— **Five new apple rootstocks.** Rep. E. Malling Res. Sta. for 1952 (1953), 169-70.

E380 Rogers, W. S. and Goode, J. E. **Irrigation requirements of fruit orchards.** Rep. E. Malling Res. Sta. for 1952 (1953), 171-3.

E381 Garner, R. J. **Double-working pears at budding time.** Rep. E. Malling Res. Sta. for 1952 (1953), 174-5.

E382 Wilson, Dorothy J. **Notes on some strawberry varieties.** Rep. E. Malling Res. Sta. for 1952 (1953), 176-8.

E384 Mosse, Barbara G. **Fructifications associated with mycorrhizal strawberry roots.** Nature, Lond., 1953, **171**, 974.

E385 Preston, A. P. **A new series of apple rootstocks.** Gdng ill., 1953, **70**, 255.

E390 Villiers, F. H., Dixon, T. V. and Macneill, M. M. **The Experimental Farm.** Rep. E. Malling Res. Sta. for 1952 (1953), 15-19.

II. STATISTICS AND RECORDS

By T. N. HOBLYN and S. C. PEARCE

Design and analysis.

With the removal of the National Fruit Trials to Brogdale Farm, near Faversham, the Section has assumed responsibility for the statistical aspects of the work. In all, this has been another busy year, the number of plans required having largely increased, though the total number of statistical analyses called for was reduced from 633 to 531. Help to outside bodies has continued, notably to the Scottish Horticultural Research Institute.

East Malling.

A feature of experimental design has been the increase in the proportion of trials planned both on material that has already been used experimentally and on calibrated trees, as compared with trials for which material has been specially planted. This reflects both a shortage of land and the coming into use of methods developed in recent years and now proving satisfactory in practice. Fewer statistical analyses were required than in 1952 (456 as against 604), but this may be at least partly because the records of several considerable trials had been analysed in detail in the previous year. It is hoped, in future, to spend more time on the prior examination of data obtained from long term experiments before selecting the actual measurements on which statistical analyses are carried out ; this may reduce the number of routine analyses, though it will mean no less work for the statisticians engaged in assessing the experimental results. Once again most analyses were made for members of the Pomology Section, but it is noteworthy that this year the number carried out for members of the Plant Pathology and Plant Protective Chemistry Sections more than doubled. Greater use is being made of general methods of analysis available for designs that are complex, either from being planned so originally or from subsequent mishaps.

N.A.A.S. Experimental Horticulture Stations.

Many trials have been planned for Luddington, Efford, Fairfield, and Rosewarne. Although records are now being made on a number of trials, no analyses of data have yet been called for.

N.A.A.S. Provincial Experiments.

Plans have been prepared for several experiments and also for some demonstration plots. Data are now being received and 49 statistical analyses were carried out as compared with 10 in 1952.

National Fruit Trials, Brogdale.

The transfer of the National Fruit Trials to Brogdale, where the first trials will be planted in 1953-54, has been the occasion for much thought in the planning of the various experiments to be planted there. These include both *preliminary trials*, in the course of which a large number of varieties, the potentialities of which are largely unknown, are to be assessed as quickly as possible, and *main trials*, during which the more promising new varieties, selected after preliminary trial, will be compared with standard ones in more detail in permanent plantations. Some varieties have already been selected for planting at once in permanent trials. The following estimated numbers of varieties of top fruits alone for trial give some idea of the magnitude of the task :—

Apples.		Pears.		Plums.	
Unit.	No. of varieties.	Unit.	No. of varieties.	Unit.	No. of varieties.
Preliminary trials. 8 trees on M.VII	106	8 trees on Quince A	26	8 trees on Myrobolan B	25
Main trials. 12 trees on M.II	23	12 trees on Quince A	11	12 trees on Brompton	22

Statistical research.

This year has seen the consolidation of the research programme, work being concentrated on some of the more important problems.

Methods of experimental design and interpretation.

Attention has been given principally to the problem of changing treatments in a long-term trial. The possibilities using partial balance have been examined, and this had led to the development of some interesting though complicated designs that may well be of value when more obvious methods are not available. A general method for determining the efficiency of these designs has been evolved. A general survey and classification of these methods of layout was prepared for the Third Biometric Conference.

Statistical methods have been developed for studying the manner of spread of disease among trees, etc., planted in rectangles. A report will appear shortly.

Two publications have dealt with general questions of trial design and interpretation with perennials. The larger (M20) has surveyed the whole field ; the smaller (M21) has set out recent developments in trial design.

In collaboration with the Pomology Section, some preliminary tasting trials have been carried out on soft fruit and apples, and studies made of technique.

Plant variation and sampling.

Studies continued on the use of eye estimates for weight of crop of individual trees. Attempts have been made to estimate the crop weight for plots of strawberries by weighing only some of the pickings but without success.

Work has continued on the information that may legitimately be inferred from trunk girths of apple trees, special attention being given to the position on the trunk at which the girth is measured.

A method much used in North America of measuring the vigour of apple trees by sampling for the mean growth per shoot has been tried out at East Malling, so far with inconclusive results.

Field trials.

Records have continued on the apple uniformity trial. In the trial on the restoration of uniformity of land, in collaboration with the Pomology Section, one half of the plots have now been planted with M.VII apple rootstocks. These have been budded *in situ* with Cox's Orange Pippin and Tydeman's Late Orange. The growth of the trees of the former variety during 1954 and 1955 will provide an indication of any fertility patterns left behind by the large Bramley's Seedling apples that grew on the plots until the winter of 1949-50. The plots in the other half of the field will be devoted to arable crops for four more seasons, after which they too will be planted with apple rootstocks as above.

PUBLICATIONS DURING THE YEAR.

20 PEARCE, S. C. **Field experimentation with fruit trees and other perennial plants.** Tech. Commun. Bur. Hort., E. Malling, 23.

21 PEARCE, S. C., JOLLY, G. M. and FREEMAN, G. H. **A review of experimental design at East Malling, 1948-1952.** Rep. E. Malling Res. Sta. for 1952 (1953), 83-7.

III. PLANT PHYSIOLOGY

By H. W. B. BARLOW

Collaboration has continued between the Plant Physiology Section and the Research Institute of Plant Physiology under Professor F. G. Gregory, and the following report includes work of the latter's staff carried out at East Malling.

Physiology of growth and form in fruit trees.

A satisfactory third year's growth of the stock on stock trees has brought the first part of the experiment to a close, i.e. the analysis of the growth of juvenile trees. For the second part of the experiment half of the remaining 600 trees have been disbudded, to investigate the effect of flowering on growth and vice versa. A brief account of this experiment is given on page 141. Many of the trees flowered this year and it was evident that both stock and scion can strongly influence the amount of blossom, a given variety having a similar effect in either capacity. A quantitative relation was found between the proportion of trees flowering in any treatment and the average number of blossoms on each tree.

Measurements have been taken this year which, for the first time in these studies, should give estimates of total cambial area.

A new field experiment has been planted to obtain further insight into the problems of fruit bud differentiation. The modifying factors considered were rootstock (M.XVI and M.IX), scion variety (Worcester Pearmain, Cox's Orange Pippin, Laxton's Superb, and Miller's Seedling) and pruning (light or heavy, with, in a subsidiary experiment, no pruning at all). The effect of disbudding on growth will also be investigated.

An investigation of some of the internal factors controlling internode extension in apple shoots has been completed. It appears that the controlling effect of the shoot tip may lie mainly in the very young leaves, and that the effect of the leaf becomes progressively less as it ages. The influence of the leaves appears to be additive, but, whereas the growth of internodes which have reached about a quarter of their final length or more is promoted by the leaves above them, in the very young internodes there seems to be a large effect of the rudimentary leaves below.

Cell size, in both meristematic and mature cortical regions near the tip of the shoot, was found to be very similar in M.IX, M.II, M.XVI, and Crab C rootstocks, but the number of leaf primordia in the top 2 cm. of the shoot was lowest in M.IX, highest in Crab C, and intermediate in the other two.

Mineral nutrition and growth.

Reports of this work, provided by staff of the Research Institute of Plant Physiology, have previously been included with those of the Biochemistry Section.

M.IX and Crab C stocks in sand culture have shown the expected response to nitrogen, but little difference in the growth of these contrasting stocks has occurred so far ; the experiment is being continued for another year.

Earlier studies of the factors affecting the growth of root cuttings of M.IX, M.II, and M.XVI in water culture were extended, in particular to include the concentration in the medium of hydrogen ion, carbon dioxide, and oxygen, and the form in which iron is supplied. A marked effect of aeration on pH change of the medium was observed, this treatment being beneficial when deep culture vessels were used.

Water and sand culture experiments were set up to follow the migration of manganese from the parent leaf into the shoot of leaf-bud cuttings of M.V by analysis of the various parts.

Hormone relations in fruit trees.

Several years' observations on net auxin and inhibitor levels in vegetative shoots of apple and plum rootstocks, using the coleoptile curvature method of assay, are now being integrated into a picture of the natural hormone relations of these shoots throughout their maiden year, during dormancy, and into the period of renewed growth in the second year.

The separation by paper chromatography of the growth promoting and inhibiting substances in these shoots has been continued, and it is hoped that this work will soon link up with the previous studies and with those on internode growth. This season's work has confirmed the presence of the five promoters and three inhibitors described in last year's Annual Report (page 88) and some of the characteristics of the inhibitors have been studied using the coleoptile straight growth test.

Vegetative propagation.

Investigations last year into the storage of hardwood cuttings of apple and plum rootstocks led to further experiments again carried out jointly with the Pomology Section. Other treatments to induce early rooting, particularly in Crab C, were tested, including mixed growth substance dips of β-indolylbutyric acid and α-naphthylacetic acid in varying proportions, and water soaking, to leach out possible natural inhibitors, followed by growth substance dips.

Fruit drop, including thinning.

A further experiment was conducted jointly with the Entomology Section to determine the effect of certain sprays, applied to control Apple Sawfly, on the shedding of fruits from Worcester Pearmain and Cox's Orange Pippin throughout the season. These results are considered along with those of experiments conducted in the years 1949-51.

A small experiment was performed in collaboration with the Pomology Section on Miller's Seedling apples to test the effect of NAA sprays on thinning the young fruits. Two concentrations and two times of application were tried, but no treatment was effective.

Spray damage.

In collaboration with the Plant Protective Chemistry Section, work was undertaken on the determination of the rate of penetration of copper sulphate into apple leaves ; it was found that the amount which entered the leaf and caused damage was negligible compared with the large quantity adsorbed on the surface. It appears that damage at a distance from the site of application may result from the formation of a toxin under the influence of the copper rather than by movement of the copper itself within the tissues.

In the course of the year, rapid routine methods of estimating spray deposits on single leaves were developed for both copper and lime-sulphur (see pages 180 and 182).

PUBLICATIONS DURING THE YEAR.

F70 HANCOCK, C. R. and BARLOW, H. W. B. **The assay of growth substances by a modified straight growth method.** Rep. E. Malling Res. Sta. for 1952 (1953), 88-94.

F71 VYVYAN, M. C. and TROWELL, G. F. **A method of growing trees with their roots in a nutrient mist.** Rep. E. Malling Res. Sta. for 1952 (1953), 95-8.

F72 BOLAS, B. D. and RUCK, H. C. **Some effects of the addition of carbon dioxide to soil of pot cultures of Malling V apple rootstocks.** Rep. E. Malling Res. Sta. for 1952 (1953), 99-103.

IV. BIOCHEMISTRY

By W. A. ROACH

Analytical methods.

Following the formation of a sub-committee of the A.R.C. Conference on Mineral Deficiencies to compare analytical methods, a study of five typical samples of plant material has been undertaken in collaboration with four other centres. Attention so far has been confined to the elements nitrogen, phosphorus, potassium, calcium, magnesium, manganese, and iron.

Micro-chemical methods.

Considerable attention has been devoted to the development of micro-chemical methods for estimating copper, zinc, silicon, and sulphur in plant material by adapting both new and well established methods. All the methods tried proved unsuitable for small samples with the exception of that for silicon. The latter can now be estimated on 10 mg. of dried material without preliminary separation from phosphorus. Work on boron, copper, zinc, and sulphur will be continued as opportunity offers.

Spectrographic methods.

Flame method.—During the year the use of Long Range Spectrum Plates was investigated in detail in the hope that they would make possible the routine determination of lithium and rubidium with little additional work. An internal standard powder was compounded for use with these Plates and standard curves were produced for calcium, potassium, magnesium, iron, manganese, and copper.

The sensitivity of different batches of Long Range Spectrum Plates was found to vary so seriously that their use was abandoned in favour of Chromatic Plates.

It was found that the low slope of the standard curve for magnesium rendered this technique unsuitable for its determination, while emission by iron was found to be suppressed in proportion to the amount of calcium present.

Arc method.—One of the limiting factors in the use of the arc for detecting traces is the background due to cyanogen bands. These can be eliminated by arcing in a nitrogen-free atmosphere. Atmospheres of oxygen, steam, and carbon dioxide were tried, and oxygen is being used at present. The electrodes are consumed faster, but the background is much lower than that from arcing in air. Using this modification and with electrode shapes chosen after extensive work on this aspect we can now detect zinc, molybdenum, and nickel present in the ash of 20 mg. of a normal apple sample. Much additional work on the mutual interactions in the arc will be necessary before quantitative estimations can be made on samples of this size.

Studies in nutrition.

Analytical determination.

In the past two seasons some thousands of leaf samples have been taken for analysis in connection with nutrition experiments (both spray culture and field experiments), with comparisons of clean cultivation, swards, and straw mulches, and with studies of the effects of spraying or injecting trees with selected elements. Other series have been collected for studies of the relation between mineral status and biennial bearing, and of the effect of the rootstock scion combination upon mineral composition.

The leaf sample taken has been of the type found satisfactory in the past, i.e. the uppermost fully expanded leaf of an extension shoot. The developments in analytical methods noted above, which permit of the analysis of a single leaf for a number of elements, has made it possible to re-examine the question as to the best type of leaf sample for particular purposes. In nearly all cases, therefore, in addition to the standard samples, leaves have been collected from other positions on the shoot for micro-chemical analysis, or whole shoots taken to allow of the analysis of individual leaves by spectrographic methods.

Already there are indications of clear cut effects of artificial manuring, clean cultivation, cover cropping, straw mulching, and of both rootstock and scion on mineral composition, and of differences in mineral composition between shoots from ‘ on ’ and ‘ off ’ year trees, but it would be unwise to draw any definite conclusions until the full number of replications are analysed.

It may also be mentioned that trees growing under straw mulch have been found to produce fruit with a high potassium content compared with fruit trees under grass or clean cultivation. A similar effect is also found in the leaves in October but not in July. The different cultural treatments also produce differences in nitrogen content of leaves, whether sampled in July or October, which reflect the vigour of the trees.

Magnesium deficiency.—The spraying experiment described in last year's Annual Report (page 32) was continued for a further year, and extended to determine to what extent the effect of the spray on the Fruit Tree Red Spider Mite, noted earlier, was due to a direct effect of the magnesium sulphate, and how much to an effect of the magnesium sulphate on the tree and only indirectly on the Red Spider. The examination of the large numbers of records involved is not yet complete.

Growth of rootstocks in stool- and layer-beds has been poor in certain areas ; this has usually been associated with a leaf scorch of the magnesium deficiency type. A preliminary experiment showed that spraying with 2 per cent magnesium sulphate lessened the amount of this scorch without, however, having any visible effect on growth. An experiment was, therefore, undertaken on a larger scale. Nine sprays were found to reduce the amount of scorch considerably, but three sprays had little visible effect. The growth records are not yet complete.

Iron deficiency.—A preliminary trial was carried out on the use of iron complex of ethylenediamine tetra-acetic acid as a spray in the treatment of lime-induced chlorosis in apples. The treatment was only partially successful.

Organic constituents of fruit plants.

The ethylacetate soluble fraction of apple and pear leaves has been found (see page 37) to depress the growth of apple and pear scab fungi, both in artificial culture and when injected into the living leaves. Progress has been made in the examination of this fraction, which consists of glycosides, tannins, etc.

The method for the direct measurement of absorption spectra of spots on a paper chromatogram (K96) has been extended by including in the study a wide variety of organic compounds, which either occur themselves or are closely related to those present in fruit trees. This has rendered possible general deductions from the absorption spectra as to the structural type of the compound being examined.

Further work on the determination of soluble carbohydrates in fruit plants by oxidation with sodium metaperiodate has made it possible to apply the method to minute quantities of sugar. The use of notatin (a specific oxidase for glucose), coupled with an improvement in the ferricyanide method for determining reducing sugars, has been of great value in the search for a suitable means of determining starch in woody tissue, but work has been impeded by the difficulty of obtaining supplies of notatin.

In view of the effect of manganese deficiency on the organic composition of the potato, noted in 1950, different plants found showing signs of mineral deficiency were injected in one side of the leaf with the deficient element ; then the two half-leaves were examined comparatively. There were further indications of clear-cut differences in organic composition resulting. This apparently promising method will be further developed as opportunity offers.

Spray culture of apple rooted shoots.

The improvements in the apparatus described in last year's Annual Report (page 33) were completed in early June. M.VII rootstocks were grown successfully from then until the end of the season in full nutrient solution and in solutions deficient of iron, of magnesium, and of both iron and magnesium respectively.

Throughout the season a cheap and simple method for water purification has been in use. In this a precipitate of calcium carbonate, followed by one of calcium phosphate, entrain most of the iron and manganese. After the pH is adjusted, the water is ready for use and is suitable for water culture involving deficiencies of magnesium, iron, manganese, and potassium.

PUBLICATIONS DURING THE YEAR.

K92 VANSTONE, F. H. **A quantitative flame spectrographic method for plant material.** Trans. Int. Soc. Soil Sci., Dublin, 1952, **2**, 292-3.

K96 BRADFIELD, A. E. and FLOOD, A. E. **The direct measurement of the absorption spectra of some plant phenols on paper strip chromatograms.** J. chem. Soc., 1952, 4740-4.

K98 MASON, A. C. **The determination of small amounts of calcium in plant material.** Analyst, 1952, **77**, 529-33.

K99 ——— **The cleaning of leaves prior to analysis.** Rep. E. Malling Res. Sta. for 1952 (1953), 104-7.

K100 ——— **Note on the determination of nitrate in culture solutions.** Rep. E. Malling Res. Sta. for 1952 (1953), 108.

K101 BRADFIELD, A. E. and FLOOD, A. E. **Chlorosis in apple leaves.** Rep. E. Malling Res. Sta. for 1952 (1953), 109-11.

V. PLANT PATHOLOGY

By R. V. HARRIS

Bacteriosis of cherry (*Pseudomonas mors-prunorum*).

Leaf-scar infection.

This important infection phase was further studied relative to time of inoculation, mode of abscission, and admixture of inocula with a saprophytic bacterium commonly occurring in normal leaf-surface populations.

The evidence from a series of weekly inoculations of a resistant and sensitive variety, through leaf-scars naturally induced by prior removal of the leaf lamina, suggested that under natural conditions most infections may occur through scars formed by the occasional fall of leaves early in the leaf-fall period. With a lower concentration of inoculum similar results were obtained.

In a parallel inoculation series, where scars were exposed by pulling off leaves, the effect was to increase the severity of disease symptoms at all times of inoculation, from which it is concluded that the severity of effects following normal leaf-scar infection tends to be limited by host changes, either physiological or anatomical, naturally occurring during the general leaf-fall period.

The effect of using mixed inocula containing the saprophytic bacterium referred to above was further investigated by leaf-scar inoculations on two varieties. Considerable reduction in the consequent disease rating occurred when the saprophyte was present in the inoculum, but only when in a viable condition. The inhibitory effect therefore appears to be due to the biological activity of the saprophyte after entering the vascular traces of the leaf-scar.

Leaf-surface bacterial populations.

From further quantitative estimations on other sites results were obtained similar to those of the previous year, thus establishing that a higher population of bacteria is normally sustained on the leaves of the less resistant cherry varieties, irrespective of season, locality, or age of tree.

Spray trials.

Two successive seasons' results from a trial on the Schrecken variety to test the efficacy of an additional spraying with Bordeaux mixture applied in mid-September, showed a considerable improvement on the degree of control obtained by the normal spray schedule at present recommended. The defoliant action of this extra spray was also tested on twelve other cherry varieties.

Cauliflower of strawberry and related diseases.

In a further analysis of the disease complex, made in collaboration with the Entomology Section (see page 44), by the inoculation *in vitro* of seedling plants of *Fragaria vesca*, symptoms were produced for the first time using the bacterium *Corynebacterium fascians* alone. These, however, were dissimilar from the symptoms of true Cauliflower, the latter only occurring when eelworm also was present. It is thus suggested that, although Cauliflower symptoms are mainly caused by this bacterium, their characteristic form is the result of modification of the action of the bacterium by the eelworm.

Apple and Pear Scab investigations (*Venturia* sp.).

The fundamental study, in collaboration with the Biochemistry Section (see page 35), of the inherent causes of host resistance was continued with particular reference to the reaction of certain constituents of the aromatic fraction of host extracts on the growth and sporulation of the fungus *in vitro* and *in vivo*.

Using potted apple and pear trees of various stock/scion combinations, the polythene sleeve method of inoculation, and a modification of the Roach method of diagnostic petiole injection, a series of eleven experiments was made from April to October. The earlier of these were made on shoots raised under artificial light in a heated house. Trees of Cox's Orange Pippin and Worcester Pearmain apple, and Williams' Bon Chrétien pear, were injected at various times immediately before and during the incubation period of infection with the aromatic fraction from tree extracts, or purified constituents of it, separately and in combination with certain amino-nitrogen compounds. The results in terms of the area of scab lesions on the leaves varied greatly according to the injectant. Thus, in the case of four trees of Cox on M.IV, injected with the aromatic fraction of a Cox extract one day after infection with a pure isolate of *V. inaequalis*, a high degree of scab inhibition was recorded. Conversely, in a series of parallel injections with a mixture of the aromatic fraction and an organic nitrogen source (urea) no inhibitory effect was recorded.

In parallel cultural studies of the pathogens *in vitro*, the inhibitory action of the Cox aromatic fraction was also variously reduced when in combination with amino-nitrogen sources.

The disease reaction of the leaves of a treated shoot in these tests has thus been found to depend, basically, on the pathogenicity of the isolate inoculum, and on the sensitivity of the host variety in so far as the latter is determined by the occurrence of a particular nitrogen-aromatic balance in the normal host tree, and it seems that this balance can be influenced, at least temporarily, by tree injection with one or other of these tree constituents.

Verticillium Wilt of hops (*V. albo-atrum*).

Fundamental studies.

Work on this aspect of the programme was again necessarily retarded following the staff changes of 1952 and the competing demands of our *ad hoc* field trials of new Wilt-tolerant seedlings, but should resume its normal progress in 1954. Some advance, however, was made in the investigations of the toxic metabolites of the pathogen, the effect of fungal invasion on the water transporting system of hop stems, the process of initial root entry and the subsequent infection path of the pathogen within the host, and the relative roles of root and stem in the Wilt process as studied by graft complexes.

The examination of the effects of crude culture filtrates on the water relations of hop shoots was completed, and the results are being prepared for publication. Modifications in culture medium and technique have given promise of improved toxin production. Some success was obtained in the extraction of a toxic constituent by ethanol precipitation.

A technique for comparing water transport facilities in normal and Wilt-infected stems showed that considerable resistance was induced in the latter, and that such resistance was associated with the presence of numerous tyloses in those vessels in which transport had been restricted.

The experiment to determine the method of entry of the fungus into the host roots and its subsequent invasion path proceeded according to plan, but the results are not yet available.

A series of graft combinations of Keyworth's Midseason (OR.55) and Fuggle were set up and root-inoculated with a progressive strain of *V. albo-atrum*. The results indicated that no ' resistance chemical ' operated from the roots of the Wilt-tolerant OR.55 and that root impairment by the fungus was not an important factor in the development of Wilt symptoms.

Primary field tolerance tests of new hop varieties.

Seventy-seven new seedlings in the Wye-East Malling series were given a three-plant test, and on the results, together with cultural observations at Wye, 29 were retained for more advanced tests and observations. Of the remaining 232 seedling varieties (selected in 1952 on single-plant tests) a small number were rejected on purely cultural grounds at Wye, and the remainder were propagated for advanced tolerance tests in 1954.

Twelve seedling varieties were submitted for test by Professor Salmon and of these one (OZ97a) showed moderately high tolerance.

Pathogenicity trial of Verticillium isolates.

Using as indicators Fuggle plants grown in pots contained in concrete tanks designed to obviate soil contamination, a first trial of a routine method for classifying isolates from incipient outbreaks as progressive or fluctuating strains was successfully concluded (see page 158).

Farm and brewing trials of new Wilt-tolerant varieties.

A further year's records and observations were made on trials of the East Malling seedlings C2, D1 and D3, on Progressive Wilt sites on three farms in the Paddock Wood area.

Following upon a decision of the Hops Committee of the Institute of Brewing the 1953 crops from the trials of C2 and D3 were placed at the disposal of the Institute for a second large-scale brewing trial. D1 unfortunately was not picked. Wilt records were also made on a commercial trial plot of the Wye seedling OT.48 (' Bramling Cross '), also included in the brewing trial. Two farm trials of the East Malling seedling J2 were established on two farms of growers in the Progressive Wilt area.

Verticillium-free stock of Wilt-tolerant seedling 1147.

Following the release of this seedling to the Industry by Messrs. Whitbread, we undertook to produce a tested Verticillium-free stock from the suspect material available. At the close of the season 95 tested rooted laterals were available for development in 1954.

Virus diseases of hop.

Experiments to test the efficiency of the imported Early Prolific hop as an indicator of hop viruses showed that, although this variety provides no improvement on the standard indicators for the diagnosis of Mosaic disease, it is the most efficient indicator for Nettlehead so far tested. Symptoms were recognized as early as 12 weeks after graft infection, but the maximum incubation period has yet to be determined. The results of preliminary experiments suggested that the efficiency of this indicator variety may be improved by a modification of existing transmission techniques.

Experiments in insect-vector determination included surveys of insect populations in two gardens in which Nettlehead was known to be spreading. The insects thus collected were subsequently tested. Experiments were started to examine the Hop-Damson Aphid, *Phorodon humuli*, further as a vector of Mosaic, and to test the Potato Aphid, *Macrosiphum euphorbiae*, as a potential vector of this disease. Similar experiments were made with Cobb's Mosaic and Split Leaf Blotch.

No complete or permanent inactivation of hop viruses by heat treatment has yet been achieved, but the results obtained last year suggested further experiments, the results of which are still pending.

A field trial on a farm in the West Midlands showed that the varieties tested differed significantly in the apparent rate at which Nettlehead was naturally transmitted from plant to plant. The validity of the criterion of spread employed, namely symptom expression, will be tested next year.

Virus diseases of tree fruits.

Apple viruses.

Apple Mosaic.—Further work on strains of this virus indicated that mutual antagonism exists between some, with the possibility of protection by mild strains. Additional evidence was obtained that a severe strain may be unevenly distributed among the buds of a single bud-stick. Two plum viruses with different symptoms on this host have now been shown to produce a mosaic-like symptom on apple. Heat inactivation experiments were started.

Rubbery Wood.—Preliminary results of last year's indexing of trees in various Research Station trials became available and show a wide distribution of this virus in many varieties. The almost total infection of one variety, and the entire freedom of another variety, in one field trial indicates that spread in the orchard rarely occurs. Regarding the as yet incomplete symptom readings of the 8,000 maiden trees from the 1952 stock tests, it is of interest that no indication of the rubbery wood virus has been found in any of the recently issued Malling-Merton rootstocks. Of the old Malling series, the Research Station stools of M.II and M.XII appear to be completely free ; doubtful cases were recorded in M.VII, M.XVI, and Crab C ; and most of the tested stools of M.I and M.IX proved to be infected but only one of M.IV. Considerable progress has been made in the multiplication of new stoolbeds from virus-tested originals selected during the course of these tests. Over 6,000 new tests by double budding were set up. An investigation of a rubbery condition of certain apple varieties other than Lord Lambourne, and possibly distinct in origin from the common Rubbery Wood disease of the latter, was started.

Pear viruses.

The results of last year's extensive indexing of pear scion varieties have shown a wide distribution of infection by viruses causing four distinct symptom types on the indicators, quince seedlings. The search for improved indicator species continued.

Cherry viruses.

In further work on identification attempts were made to graft-transmit rasp-leaf and rosette viruses from artificially infected F12/1 stocks to the Canadian indicator varieties Napoleon and Montmorency. Severe rasp-leaf virus caused a high proportion of the Napoleon grafts to fail. By such transfers a rosette virus fromSchrecken was found closely to resemble that causing Mottle Leaf in the United States. In tests for virus-free wood of the variety Amber only one tree of the ten clonal sources sampled was found to be apparently healthy. It is interesting that this tree was an isolated one in a private garden. Heat treatment was tried to obtain a virus-free source of Roundel. This work is finding immediate practical application in the Station's release of mother trees propagated from virus-tested material, to provide sources of virus-free propagation material for the nursery trade.

Plum viruses.

Of tests made on some 29 varieties, virus-free source trees of 17 were obtained. The search for improved indicators continued and results should be available next year. Symptoms resembling those of the Eastern European disease Plum Pox were observed on Early Laxton and on Warwickshire Drooper trees inoculated in 1951 with suspected virus diseases collected from commercial orchards. Symptoms of bark split virus were frequently observed in commercial orchards and nurseries of the Evesham district. Indexing experiments suggest that more than one virus may cause similar bark splitting symptoms in *Prunus* species.

Virus diseases of strawberry.

Natural spread in the plantation.

In a continued study with the Entomology Section (see page 43) spread in 1952 and 1953 was found to follow the seasonal trend observed in 1951, with peak periods in June and October.

Analytical experiments.

These chiefly comprised further experiments with the green petal virus and with the low persistence virus recently found in certain of the Cambridge Seedlings (Cambridge ' X ' virus).

Attempts to transmit the green petal virus by aphids gave consistently negative results and experiments were started to test several unidentified species of leafhoppers and froghoppers collected from strawberry fields and hedgerow plants bounding such fields.

Work on the aphid relationships of Cambridge ' X ' virus showed that it is indistinguishable on this basis from virus 1 (mild-crinkle virus) and also that leaf necrosis on *F. vesca* and Royal Sovereign is not invariably a distinguishing criterion. Crown proliferation and severe dwarfing of *F. vesca* proved to be the most reliable diagnostic and, by single-aphid transfer, a virus causing these symptoms alone was isolated from a plant infected with both virus ' X ' and virus 1.

Therapy.

As a result of further experiments in heat-therapy evidence was obtained that the virus 4 of Prentice, as well as virus 1 and virus 3, can be heat-inactivated. This year, also, using an improved heat-chamber, work was concentrated on the heat-inactivation of virus 2 ; positive results have been recorded to date on Royal Sovereign plants exposed to 98° F. for long periods. Experiments in chemotherapy also continued.

Virus diseases of bush fruits.

Gooseberry Vein-banding.

Attempts to transmit this virus to black and red currants, both by aphids and by grafting, were made with results which are as yet inconclusive. Further work on aphid-vector relationships is now yielding definite information on its persistence.

Black and red currant viruses.

Five aphid species were tested as vectors of the black currant yellows and vein-pattern viruses, and a start was made on the study of two forms of degeneration in red currants as possible virus diseases.

Fungicide investigations.

Apple Mildew.

Following the successful use last year of pot trees of the Mildew susceptible stock M.III in the greenhouse for the *in vivo* assay of fungicides, experiments this year, in collaboration with the Plant Protective Chemistry Section (see page 46), were directed towards the development and standardization of the method used then, as a preliminary to further screening tests of compounds related to dinitrocaprylphenyl crotonate.

The combined apple orchard spray programme.

As an important and logical development of our research on fungicides two extensive plantation trials were started in collaboration with the Entomology (see page 43) and Plant Protective Chemistry Sections (see page 46), to investigate the effect of a combined programme of fungicide and insecticide summer sprays on diseases and pests and on the beneficial orchard fauna, both with and without winter spray treatments.

Low-volume (concentrate) spraying.

Investigations were continued on both an intensive and an extensive scale on the application of lime-sulphur by this method against Apple Scab, Mildew, and, with the Entomology Section, Fruit Tree Red Spider Mite.

The results of a small-scale application by paint-gun of a logarithmic range of concentrations from 1 to 81 per cent, against the normal high-volume schedule, confirmed that lime-sulphur applied at very low volume was both effective and safe provided that a high concentration of lime-sulphur was used.

In the large-scale experiments on mature orchard trees a considerably modified version of the prototype machine designed and provided by the Horticultural Engineering Department of the National Institute of Agricultural Engineering was used. This machine showed greatly improved performance and gave a satisfactory deposit of the lime-sulphur concentrate (at 100 per cent) in small droplets on all except tall, dense, trees. This caused no damage and gave good control of Scab against the standard lime-sulphur schedule applied at high volume at the same time.

The control of Silver Leaf disease in plums.

Earlier work of an exploratory nature from 1944 on the use of chemotherapeutic agents injected against the pathogen in the tree was done on fully mature naturally infected trees. The investigation was revived in the present year, when it was decided to use young nursery trees of a susceptible variety (Victoria), mechanically inoculated, prior to injection with the fungicide, at a known point with mycelial cultures, and with spore suspensions obtained from naturally occurring fructifications in orchards. This year the work was limited to the study of various methods and times of inoculation, to produce trees of standard infection.

PUBLICATIONS DURING THE YEAR.

C303 CROPLEY, R. **Strawberry virus diseases.** Gdng ill., 1953, **70**, 47.

C305 CROSSE, J. E. **Bacterial diseases of stone-fruit trees in Britain. IX. Bacteriosis of apricot.** Trans. Brit. mycol. Soc., 1953, **36**, 38-45.

C310 CROSSE, J. E. and PITCHER, R. S. **Studies in the relationship of eelworms and bacteria to certain plant diseases. I. The etiology of Strawberry Cauliflower disease.** Ann. appl. Biol., 1952, **39**, 475-86.

C311 MOORE, M. H. and BENNETT, Margery. **Scab, Canker and Branch Blister of apple at East Malling in relation to nutritional treatment of the host.** Ann. appl. Biol., 1952, **39**, 588-98.

C314 PRENTICE, I. W. **Resolution of strawberry virus complexes. V. Experiments with viruses 4 and 5.** Ann. appl. Biol., 1952, **39**, 487-94.

C315 CADMAN, C. H. **Studies in *Rubus* virus diseases. IV. Yellows diseases of raspberries.** Ann. appl. Biol., 1952, **39**, 495-500.

C316 ——— **Studies in *Rubus* virus diseases. V. Experiments in the analysis of Lloyd George decline.** Ann. appl. Biol., 1952, **39**, 501-8.

C317 POSNETTE, A. F. **Green Petal—a new virus disease of strawberries.** Plant Path., 1953, **2**, 17-18.

C318 ——— **Heat inactivation of strawberry viruses.** Nature, Lond., 1953, **171**, 312.

C319 PAINE, J. and LEGG, J. T. **Transmission of Hop Mosaic by *Phorodon humuli* (Schrank).** Nature, Lond., 1953, **171**, 263-4.

C320 KEYWORTH, W. G., HITCHCOCK, Margaret M. and GOODE, Pamela M. **Verticillium Wilt of the hop. VII. Further studies on Wilt-resistant varieties.** Rep. E. Malling Res. Sta. for 1952 (1953), 112-19.

C321 PAINE, J. **Insect vector studies with Mosaic and other virus diseases of the hop.** Rep. E. Malling Res. Sta. for 1952 (1953), 120-2.

C322 POSNETTE, A. F., CROPLEY, R. and ELLENBERGER, Christina E. **Progress in the heat treatment for strawberry virus diseases.** Rep. E. Malling Res. Sta. for 1952 (1953), 128-30.

C323 Posnette, A. F. **Virus transmissions between *Prunus* and *Malus* species.** Rep. E. Malling Res. Sta. for 1952 (1953), 131.

C324 Moore, M. H. **Concentrate spraying in fruit plantations ; a review of experiments with lime-sulphur.** Rep. E. Malling Res. Sta. for 1952 (1953), 132-5.

C325 Moore, M. H. and Talboys, P. W. **Note on infection of blackberry fruits by the Brown Rot fungus, *Monilia fructigena*.** Rep. E. Malling Res. Sta. for 1952 (1953), 136-7.

C326 Crosse, J. E. and Pitcher, R. S. **A preliminary note on methods for obtaining bacteria-free eelworms.** Rep. E. Malling Res. Sta. for 1952 (1953), 138-40.

C327 Posnette, A. F. **Virus diseases and the propagation of fruit trees.** Rep. E. Malling Res. Sta. for 1952 (1953), 179-81.

C328 ——— **Virus diseases of plums.** Rep. E. Malling Res. Sta. for 1952 (1953), 182-3.

C329 ——— **The Green Petal disease of strawberry.** Rep. E. Malling Res. Sta. for 1952 (1953), 184.

C330 Legg, J. T. **The natural spread of Nettlehead disease of hops.** Rep. E. Malling Res. Sta. for 1952 (1953), 123-7.

C331 Keyworth, W. G. ***Verticillium* wilt of the hop. VI. The relative roles of root and stem in the determination of wilt severity.** Ann. appl. Biol., 1953, **40**, 344-61.

C332 ——— **Resistance of hop stems to invasion by *Verticillium albo-atrum*.** Nature, Lond., 1953, **171**, 656-7.

C333 Harris, R. V. **New Verticillium Wilt tolerant hop varieties.** Assn of Growers of the New Varieties of Hops Annual Booklet, 1953, 10-15.

VI. ENTOMOLOGY

By A. M. MASSEE

Tree fruits.

The eight apple seedlings of the parentage (Northern Spy × Laxton's Superb*) × Cox's Orange Pippin, which proved highly resistant to attacks of the Woolly Aphid (*Eriosoma lanigera* Hausm.) last year, have been tested again this season, and the marked degree of resistance has been maintained. In addition, some five hundred seedlings, derived from crosses between Cox's Orange Pippin and three resistant seedlings from an earlier series, have been tested. The parentage of the latter were respectively Northern Spy × Winter Majetin, Northern Spy × Laxton's Superb, and Northern Spy × Malling I. Thirty-two per cent of these seedlings proved very resistant to Woolly Aphid attack and are being retained for further tests next year.

Counts of capped blossoms due to attack by the Apple Blossom Weevil (*Anthonomus pomorum* L.) have continued on selected plots in order to observe the rate of reinfestation following the elimination of the pest in 1948. So far, reinfestation has been negligible.

Detailed study of the biology of the Winter Moth (*Operophtera brumata* L.) is being continued. Traps have provided information on the flight period and activity of the moths, while the period of hatching of the ova, and its relationship to the bud stage of the host plant, has been noted for two seasons, and the development of the larvae followed from field samples. Data have also been obtained on the biology of closely allied species ; eight of the ten British species of subapterous Geometrids have now been found in the vicinity of East Malling, the remaining two being confined to more northerly localities.

The infestation of the Pear Sawfly (*Hoplocampa brevis* Klug), which was first noted in the Rochester district of Kent in 1949, has been eliminated from the three orchards in which it originally occurred, but a new outbreak has been observed in a young pear plantation a few miles south.

The Pear Sucker (*Psylla pyricola* L.) has again been common in many pear plantations in Kent ; further observations have been made on its life cycle.

The work on the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* (Koch)) has been continued for the tenth year at the Field Laboratory, Great Braxted, Essex, and also at East Malling. In Essex winter eggs were first noted hatching late in April, but the larval forms were not prevalent until the third week of May, while the initial signs of foliage discoloration were noted on 26th May.

Mite dispersal was not recorded until the latter part of August and in September, when it became general in Essex orchards.

Broadly speaking a commercial control of the Mite was obtained in Essex orchards, but by the latter part of the summer the build-up of mite populations had become evident on many fruit farms.

The large-scale summer spraying trial of ovicides and acaricides was continued, with certain modifications at the Essex Institute of Agriculture, Writtle, in the orchard of Laxton's Superb used last season. Initially both treatments of DPS and CPBS reduced the mite populations very considerably. Later in the year, however, there was a considerable build-up in the mite infestations on the DPS plots. On the other hand, the mite populations of the CPBS plots were very much smaller by the end of the summer, and the green colour of the foliage persisted throughout.

Two additional ovicide/acaricide trials were carried out on bush trees of Worcester Pearmain and Cox's Orange Pippin at Galleywood, Essex. The treatments of CPCBS, with and without an acaricide, gave a very high degree of control on Worcester Pearmain, but the DPS preparations, very promising until the end of July, failed to hold the mite late in the season and high winter egg populations built up. Six treatments of CPBS, applied at different times, and at varying strengths, on Cox's Orange Pippin, all provided excellent control of the mite. By the latter part of September the CPBS treatments (0·05 per cent) applied at pink bud and petal fall, and similar sprays applied twice at the fruitlet stage in June and three weeks later were outstandingly good, the mite populations being very low and the foliage still a fresh green colour. None of the treatments caused any injury to the foliage of the Cox trees, but the higher strengths caused a little fruit cracking at the end of July. The James Grieve pollinator trees in the same trial were damaged by all CPBS treatments, the injury being more apparent on the trees which received two applications of spray at the higher strength at the fruitlet stage. It was mainly confined to the spurs and fruit buds.

A study of the beneficial insects associated with the Fruit Tree Red Spider Mite has continued. Routine records of predator populations were taken on two of the field spraying trials. In addition, some of the ovicides/acaricides used in the field trials were applied on other trees later in the season to determine their effect on particular predator species. A final year's records were taken at Ryarsh, Kent, where a trial to assess the effects of fungicides has been in progress for three years ; a similar trial at Stondon Massey, Essex, was continued in collaboration with the Plant Protective Chemistry Section.

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* Cox's Orange Pippin × Wyken Pippin.

Biological studies of the predatory mites were continued. Breeding of these mites was carried out with some success, and the number of generations each year and their feeding capacity has been investigated.

A study is also being made of the overwintering site and migration of several predaceous species.

The life histories of various predators, including some of the spiders, is being studied and the Arthropod faunae of commercial and of derelict orchards are being compared. In addition, the rôle of natural cover—such as copses, hedgerows, and scrub land bordering on orchards—in initiating or maintaining a high predator density in the orchard is being investigated.

A study of the integrated action of insecticides and fungicides on the Fruit Tree Red Spider Mite is being made in collaboration with the Plant Pathology and Plant Protective Chemistry Sections. Two field trials have been started at the Station to study the effects of various insecticides and fungicides on populations of predatory insects and of the Fruit Tree Red Spider Mite.

Detailed biological studies of the aphids of apple, pear, red and black currant, and gooseberry are in progress. Preliminary observations have been made on the *Prunus* aphids.

Field trials have been carried out to compare the efficiency of sprays applied shortly after the hatching of the eggs with that of winter washes.

For a fourth year, records of the flight period of adult Codling Moths and the emergence of the Moths from stocks of larvae overwintered under various conditions have been obtained ; theparasites and other agents of natural control of this insect have been studied.

A spraying trial was undertaken in collaboration with the Plant Protective Chemistry Section, using various formulations of DDT and assessing the value of each by the degree of Codling Moth attack, and by biological laboratory testing.

The mercury vapour light trap has been used to obtain records of the flight periods of many species of Tortricid moths frequenting the orchard. The flight periods of the Codling Moth and the Summer Fruit Tortricid have been particularly noted.

Trials to find more practical measures for the control of the winter and summer generations of the Summer Fruit Tortricid are being conducted with the Plant Protective Chemistry Section.

The incidence of Root Lesion Nematodes (*Pratylenchus* spp.) on the roots of tree fruits is being investigated now that new methods of extracting the eelworms are available.

The annual cycle of a plum cambium miner (*Dendromyza* sp.) has now been established, and specimens of all the stages have been obtained to aid in the identification of the species. Biological studies are being continued.

Small fruits.

Experiments on the chemical control of the Strawberry Eelworms (*Aphelenchoides ritzema-bosi* (Schw.) and *A. fragariae* (Ritz-Bos)) and the Stem and Bulb Eelworms (*Ditylenchus dipsaci* (Kuhn)) have continued to give encouraging results. In collaboration with the Plant Protective Chemistry Section some attention has been devoted to the mode of action of organophosphorus materials.

Field trials on the persistence of *A. ritzema-bosi* in the soil have reached the stage when the first indicator plants can be set out. Studies with the Plant Pathology Section on the etiological relationship of *A. ritzema-bosi* and *Corynebacterium fascians* (Tilford) Dowson in strawberry diseases are continuing. The rôle played by the bacterium is now known with more certainty, but further modifications of technique are needed before that of the nematode can be satisfactorily defined.

A survey of the incidence of Root Lesion Nematodes (*Pratylenchus* spp.) in soft and tree fruit has indicated populations in strawberry comparable with those believed to induce fungal root rots in Holland and America.

Studies on the Strawberry Aphid (*Pentatrichopus fragaefolii* (Cock.)) have continued, and counts have been made on entire plants to study leaf preferences and to evaluate the efficiency of the sampling method used for population studies. Attempts have been made to eliminate predatory insects from small experimental plots of strawberries in order to assess the effects of these insects on population changes.

Field trials are in progress, in collaboration with the Plant Pathology Section, to study the influence of various spray programmes on the incidence of virus infection.

Further trials have been carried out on the control of the Strawberry Aphid on fruiting plants. The effect of similar sprays applied under commercial conditions has been followed on the farm plots.

Various species of Strawberry Ground Beetles have been prevalent in recent years, and are responsible for much harm in commercial strawberry fields. A trapping method has been devised to study population fluctuations ; the life histories are being followed in the insectary ; experiments on control have continued.

A further field experiment on the control of the Black Currant Leaf Midge (*Dasyneura tetensi* (Rueb.)) has been carried out. This series of trials has shown that the chief difficulty of obtaining good control is one of timing, as the emergence peak of adults varies greatly from year to year, and usually falls within the blossom period. In these circumstances the insecticides used have often proved either too slow-acting or too short-lived to give effective control.

Study of Gall Mites and Parasitid Mites.

Specimens of *Phytoptid* mites received from various countries are being determined as time permits, and the mites contained in the family *Parasitidae*, some of which are closely associated with the Fruit Tree Red Spider Mite, are being studied in detail.

PUBLICATIONS DURING THE YEAR

D258 COLLYER, Elsie. **Biology of some predatory insects and mites associated with the Fruit Tree Red Spider mite (*Metatetranychus ulmi* (Koch)) in South-Eastern England. III. Further predators of the mite.** J. hort. Sci., 1953, **28**, 98-113.

D259 ——— **Biology of some predatory insects and mites associated with the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* (Koch)) in South-Eastern England. II. Some important predators of the mite.** J. hort. Sci., 1953, **28**, 85-97.

D261 GROVES, Joan R. **Summer Fruit Tortricid, is it serious ?** Commercial Grower, Jan. 1953, 202. Grower, 1953, **39**, 233 (under different title).

D263 COLLYER, Elsie. **Beneficial fruit insects ; predators 1.** Grower, 1953, **39**, 635.

D264 ——— **The effect of spraying materials on some predatory insects.** Rep. E. Malling Res. Sta. for 1952 (1953), 141-5.

D265 MASSEE, A. M. **Notes on some interesting insects observed in 1952.** Rep. E. Malling Res. Sta. for 1952 (1953), 146-50.

D266 DICKER, G. H. L. and BRIGGS, J. B. **Studies on control of Apple Sawfly, *Hoplocampa testudinea* (Klug). I. Effect of time of spraying.** Rep. E. Malling Res. Sta. for 1952 (1953), 151-5.

D267 MASSEE, A. M. **Insect population balance and chemical control of pests. Insecticides in the apple orchard.** Chem. and Ind., 1953, 1004-5.

D268 GROVES, Joan R. and TEW, R. P. **Preliminary trials for the chemical control of the Summer Fruit Tortricid.** Rep. E. Malling Res. Sta. for 1952 (1953), 156-8.

D269 COLLYER, Elsie. **The Greenhouse Red Spider Mite, *Tetranychus urticae* Koch, on apples in East Anglia.** Rep. E. Malling Res. Sta. for 1952 (1953), 159-60.

D270 ——— **Beneficial fruit insects ; predators 2.** Grower, 1953, **39**, 735.

D271 ——— **Beneficial fruit insects ; predators 3.** Grower, 1953, **39**, 837.

D272 ——— **Biology of some predatory insects and mites associated with the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* (Koch)) in South-Eastern England. IV. The predator-mite relationship.** J. hort. Sci., 1953, **28**, 246-59.

D273 DICKER, G. H. L. **Some notes on the biology of the Apple Sawfly, *Hoplocampa testudinea* (Klug).** J. hort. Sci., 1953, **28**, 238-45.

D274 COLLYER, Elsie. **Insect population balance and chemical control of pests. Predators of the Fruit Tree Red Spider Mite.** Chem. and Ind., 1953, 1044-6.

VII. PLANT PROTECTIVE CHEMISTRY

By A. H. M. KIRBY

Laboratory investigations.

Further experiments have been carried out with winter and summer eggs of the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* (Koch)). The promising results obtained earlier with chlorinated phenyl benzenesulphonates against the winter egg of this mite have been published (Q75). These ovicides were also used in collaborative investigations with Mr. W. H. Read of Cheshunt Experimental and Research Station.

Ovicides.

Further studies on changes in the susceptibility of greenhouse-laid winter eggs of the Fruit Tree Red Spider Mite towards azoxybenzene have been made, combined with an attempt to determine the dosage-mortality lines for azoxybenzene, dinoseb, and 4-chlorphenyl benzenesulphonate (CPBS).

The passage of CPBS and the dichloro-analogue, CPCBS, through apple leaves has been further examined by determining the toxicity to summer eggs of *Metatetranychus ulmi* following application of the formulated ovicide to the opposite side of the leaf. Considerable mortality followed the use of CPBS but neither that due to CPCBS nor that due to the unchlorinated ester, PBS, was significantly greater than the controls.

Another series of experiments on the hatching of summer eggs of *M. ulmi* stored under various conditions indicated that storage in a 24° C. incubator (i.e. in the dark except when counting was in progress) gave the same rate and extent of hatching as storage on the bench (i.e. in diffuse daylight and ambient temperatures). Storage in an 18° C. incubator, or on the bench shielded from light, led to a slower rate of hatching (see page 175).

Fungicides.

Technical 4 : 6-dinitro-*sec*-octylphenyl crotonate has been studied by means of the glass-slide spore-germination test and an excellent regression line obtained for *Venturia inaequalis* ; the ED_{50} value was 0·00194 per cent. As, however, a considerable proportion of the sample used appeared to be the free phenol, it is not yet clear whether the ester has any activity or not.

Copper, presented as 0·0015 per cent metal chelated with the disodium salt of ethylenediamine tetra-acetic acid, caused less than one per cent inhibition of germination of *V. inaequalis* spores compared with 96 per cent inhibition due to the same concentration of copper presented as sulphate.

Several substituted 4-nitrosopyrazoles have been found completely to inhibit spore germination of *V. inaequalis* at concentrations of about 5 p.p.m., but variation has made it impossible as yet to obtain satisfactory results in the middle concentration range. In an attempt to reduce this variation, further studies have been made on the nature of the deposit obtained on glass with various surfactants and copper sulphate ; comparisons have also been made of the results of tests where copper sulphate was applied before the spores and where it was applied with the spores. Attempts to locate the chief sources of error are continuing.

The culture of *V. inaequalis* on filter paper rolls, using 10 per cent malt as medium, has been developed into a routine method.

Spray damage.

Studies in collaboration with the Physiology Section have continued throughout the year. Permeability measurements were made with detached upper and lower epidermis of laurel ; these indicated that the rate of penetration of metallic salts varied with the nature of both anion and cation, but not with temperature over the range 25-30° C. The lower epidermis proved more permeable than the upper by a factor of at least ten. Apple epidermis appears too frail for such experiments.

A rapid method of estimating copper in the presence of leaf material, employing dry ashing and a new colorimetric reagent, has been devised (see page 180.) This method was used to study the rate and extent of penetration of copper ions into apple and pear tissue when copper sulphate solutions were applied to leaves or taken up by cut stems. The results indicate that some copper is rapidly absorbed by the leaf epidermis, but that entry to internal tissues is a slower process. The method was also used to show the movement of copper from sprayed to unsprayed leaves within a shoot ; using a rubeanic acid staining technique it was shown to take place along the leaf traces in the pattern demonstrated by Roach.

Experiments with solutions containing wetting agents showed that, on the smooth leaves of pears, the amount retained was much affected by the concentration of wetting agent present, in contrast to the results reported last year with more hairy apple leaves. The slope of the leaf surface also influenced the extent of the run-off.

A further approach to the long standing problem of estimating lime-sulphur deposits has been made by the use of ethylenediamine tetra-acetic acid (EDTA) as a reagent for the calcium present (see page 182). This method has been used to measure deposits in low-volume spraying trials.

Chemistry.

Organic.—A range of phenyl benzenesulphonates were synthesized or purified from commercial preparations in quantities from 50 to 300 grams for studies in phytotoxicity. Other compounds were prepared or purified for trials involving Apple Mildew, toxicity to predators, and wetting efficiency.

Compatibility.—CPBS, formulated in the standard acetone solution, and lime-sulphur, mixed to give final concentrations of 0·1 per cent and 2·5 per cent respectively, were examined for hydrolysis of the ester. After standing 60 hours, or after exposure for several days as a ' spray residue ' on filter-paper, this mixture contained no detectable free phenol. Hence CPBS should be unaffected by lime-sulphur up to at least 2·5 per cent in the spray tank and in new, unweathered deposits ; the action of weathering was not studied.

Analysis.—The majority of the materials used in field trials and, where necessary, for laboratory assay were analysed before use.

Parathion, applied at 0·01 per cent to Morello cherries three weeks before harvest was shown to be absent after harvest from the surface of these fruits ; the pulp, however, contained approximately 1 p.p.m. as estimated by the Averell and Norris method.

Figures for residues of lead arsenate, applied by a grower with urea and colloidal sulphur five weeks before sampling, were in line with those published by Shaw (East Malling Research Station Annual Report for 1936, page 240).

Work on methods of estimating mercury in the presence of plant material has shown that the new A.O.A.C. method is unsuitable in the presence of waxy substances such as are found on mature apple leaves or peel. So far no method has been found which would enable accurate estimations of mercury residues to be made. Some attention has been given to estimation of the phenyl mercuric ion, and collaborative work on methods of determining mercury in formulated pesticides has begun.

Studies have been made for several years on the persistence of DDT on apple bark, leaves and fruit. The accepted Schechter-Haller method for estimating small quantities of DDT and the newer method referred to in last year's Annual Report (page 43) have been found to be capable of giving accurate results provided that all the steps designed to remove interfering materials are followed. This need makes them too complicated and tedious for use in field trials where many samples must be taken. Shorter methods, such as the Alessandrini method, are not efficient.

Greenhouse investigations.

Further experiments have been carried out, in collaboration with the Plant Pathology Section, with M.III rootstocks in pots for assay of chemicals against Apple Mildew. So far no chemical has been found to give protection comparable to that given by dinitro-*sec*-octylphenyl crotonate (DNOPC).

Field investigations.

Insecticide and acaricide trials in conjunction with the Entomology Section have been continued. Two new trials have been undertaken jointly by the Plant Pathology, Entomology and Plant Protective Chemistry Sections to study the effects of various modifications in the spray programme upon the beneficial fauna, as well as upon the general incidence of pests and diseases.

Insecticide trials.

Codling Moth.—A trial was carried out to compare the control afforded by various commercial formulations of DDT. Opportunity was taken to study the effects on populations of the Fruit Tree Red Spider Mite and certain predators, but an attempt to assess the retention and persistence of the DDT failed because of wide variations within treatments and the difficulty of getting a method of estimation which was both rapid and accurate.

Summer Fruit Tortricid.—The trial for controlling the Summer Fruit Tortricid in its first generation by means of dormancy sprays as compared with DDT sprays in the spring was continued. In another trial, DDT and parathion were used against the second generation, special attention being given to timing.

Apple Sawfly.—The results of earlier trials have now been published (Q73 and Q74).

Fruit Tree Red Spider Mite.—The summer trial at Writtle was essentially a repetition of the 1952 trial, except that the concentration of CPBS was reduced to 0·05 per cent. CPBS was superior to DPS, both as regards the resulting quality of foliage and winter egg levels. Compared with 1952, much less damage occurred and no fruit cracking was seen.

Two additional trials were carried out at Galleywood, Essex. One, on Worcester Pearmain, compared the effects of DPS, with or without derris, and 4-chlorphenyl 4-chlorbenzenesulphonate (CPCBS), also with or without derris. In the other, on Cox's Orange Pippin, CPBS alone was used at two concentrations, making one application with weak parathion or two applications without any acaricides in June, and one without an acaricide at pink bud and at petal fall. All CPBS treatments and two applications of CPCBS alone gave excellent control of the Mite ; some damage to Worcester and James Grieve pollinators was caused by CPBS, whereas CPCBS and DPS caused no significant damage.

A pilot trial with three chlorinated phenyl benzenesulphonates at various timings from green cluster to petal fall indicated that all three compounds and all timings gave excellent control of winter eggs ; the standard DNC-petroleum (3 per cent oil) wash was much inferior (see page 171).

The predator aspect.

The trial at Ryarsh, Kent, begun in 1951, has now been concluded and a report will appear elsewhere.

The trial at Stondon Massey, Essex, was continued for its second year and it is hoped to continue it for at least one more year.

Trials at the Station were begun, in which a simple spray programme is being varied by introducing new pesticides (including fungicides), and the degree of pest and disease control, together with effects on predaceous insects and mites, are being recorded.

Fungicide trials.

These were confined to a trial of two specimens of zineb, one of American and one of British origin.

Apple Mildew was again controlled on Lane's Prince Albert, without damage, by DNOPC in the form of a 25 per cent wettable powder.

Spray damage.

Full use was made of the first of the phytotoxicity plots which had been completed in the winter of 1951-2. *Ad hoc* study of the effects of certain new pesticides was continued together with studies of seasonal variations. An extensive study of the effects of phenyl benzenesulphonate and several chlorinated derivatives was begun.

Publications During the Year.

Q71 Kirby, A. H. M. and Frick, E. L. **Modifications in the glass-slide spore-germination test for use in fungicide research.** Rep. E. Malling Res. Sta. for 1952 (1953), 161-7.

Q72 Kirby, A. H. M. **Common names for chemicals.** Rep. E. Malling Res. Sta. for 1952 (1953), 185-6.

Q73 Kirby, A. H. M. and McKinlay, K. S. **Some factors affecting the control of Apple Sawfly,** *Hoplocampa testudinea* **(Klug), by nicotine and other chemicals.** J. hort. Sci., 1953, **28,** 170-6.

Q74 Kirby, A. H. M. and Gambrill, R. G. **The use of some newer insecticides for the control of Apple Sawfly,** *Hoplocampa testudinea* **(Klug).** J. hort. Sci., 1953, **28,** 163-9.

Q75 Kirby, A. H. M. and Tew, R. P. **Toxicity of chlorinated phenyl benzene sulphonates to winter eggs of the Fruit Tree Red Spider Mite,** *Metatetranychus ulmi* **(Koch).** Nature, Lond., 1953, **171,** 479-80.

Q76 ——— ——— **Agricultural acaricides.** Rep. Progr. appl. Chem., 1952 (1953), **37,** 263-76.

from this external region, where the water is not mixed with anything else, to the inside of the bladder, where part of the space is occupied by sugar. You can stop the water moving from the place where the water molecules are concentrated to the place where water is not so concentrated by compressing the internal solution. The amount of compression which you have to apply to the internal solution to prevent pure water going into it is called the osmotic pressure of the solution, so that when water, having entered a cell and blown it up, raises the internal pressure up to the osmotic pressure of the solution, no more water enters.

Now, a point I want to come on to from that is how this picture of the mechanism by which the cell is blown up to high pressure fits into the structure and mechanism of a tree. You will say that this is all very well, but what gave Pfeffer this idea ? It came not perhaps from Pfeffer so much as from a Dutch colleague De Vries, who showed that, if you put outside the cell a sugar solution instead of pure water, you can produce quite a remarkable change. The effect of a sugar solution outside the cell, provided it is stronger than that inside, is that water travels from within the cell into the external sugar solution and causes part of the cell to contract away from the cell wall. Water has now passed out of the central cell sap (the central portion of the cell containing sap is called the vacuole) into the solution outside, and a bladder-like part of the cell has now been dragged away from the tough cell wall. That is what really gave the idea that the cell consisted of these two parts, the cell wall and bladder ; otherwise I do not suppose one could have discovered that structure. One might think of the analogy of a bicycle tyre. When there is a big pressure inside the tyre, the inner tube and cover make close contact. If you suck the air out of the inner tube you get a space in between tube and cover, just as one gets a space between the protoplasm, as we call the living layer, and the outer cell wall. That experiment, the breaking away of the living part of the cell from the cell wall, was what originally gave the clue, I suppose, to this view of the structure of the cell. You have, in fact, done here what is more effective than letting air out of the tyre, you have sucked air out of the tyre which, of course, becomes quite flat. Similarly when this is done to the plant cell it becomes quite flaccid, it becomes flexible, that is what happens when a plant cell wilts ; the water passes out of the cell and the cell wall is no longer stretched, and the cell loses its mechanical strength. I want to talk about trees because they are of very special interest in connection with plant water relations. The leaves of trees are composed of cells of this sort, and one of the questions we want to ask ourselves is how it is that water actually gets up to the leaves of the tree and maintains the cells of the leaves in this turgid and mechanically strong condition. These living cells make contact with long tubes in the actual trunk of the tree, in the branches of course, and the tubes in the branches make contact with the tubes in the trunk and so down to the roots. These long tubular structures had been seen by Nehemiah Grew in the seventeenth century and, because he thought they were something like the windpipe in animals, he called them ' tracheae ' ; we now call them ' vessels '. They form the tubes up which water is supposed to travel in the tree, those at the lower end making contact with living cells in the root. Cells in the root in their turn make contact with the water in the soil. Water evaporates from the cells of the leaf out into the external air in a constant flow. Now one must ask what happens when water is sucked by dry air out of a system like this. The answer that was given in the latter years of the nineteenth century was that a tree behaves so far as water is concerned something like the wick of an oil lamp. Everybody knows that the oil enters the bottom of the wick, and that it leaves at the top where it is burnt. The suggestion was that in the tree you have, in a sense, just the same process. You have a rich supply of water in the soil and relatively dry air at the top, and the trees or small plants are behaving just like wicks, and it does not matter a rap for the working of the wick mechanism whether the trunk of that tree is alive or not. Originally people had thought that it was very necessary for the trunk of a tree to be alive, that in fact the transport of water, the rise or ascent of sap as it was called, was a vital process dependent on the trunk being alive, although nobody could quite think how the living cells pumped water along the trunk. Then the suggestion was made that it did not matter whether the trunk was alive or not, and that it was acting like a wick. One of the first of the critical experiments was done in the laboratory of Professor Strassburger at Bonn around 1865. My former chief, Professor Dixon, was a student in that laboratory, and that is where his interest in the movement of water in trees undoubtedly began. Under Strassburger's guidance a tree was cut and the lower end of the trunk placed in a solution of poison—in fact of picric acid. The picric acid solution was sucked right up the trunk and appeared in the leaves which became yellow. It was then given and sucked up a second dose, and indeed three or four doses of picric acid ; it went on apparently sucking up the poison without difficulty. So it seemed as though the *living* trunk was not necessary, as though the transport of water was a purely non-living process.

Professor Dixon, in conjunction with a colleague who was a physicist, Professor Joly of Dublin, was the first to suggest the probable mechanism of this. They set up a model which is very simple. A glass funnel, closed at the wide end with Plaster of Paris and filled with water, is joined to a tube full of water, the open end of which is in a dish of water. Plaster of Paris is, of course, porous to water and,

IX. FRUIT STORAGE INVESTIGATIONS IN COLLABORATION WITH THE DITTON LABORATORY

By H. B. S. MONTGOMERY

Joint consultations between the Department of Scientific and Industrial Research, the Agricultural Research Council, Long Ashton, the Ditton Laboratory, and East Malling have enabled a considerable extension of work upon the field factors affecting storage quality. The programme, which has been developed in relation to, and is in many respects dependent upon, the research already in progress at the Ditton Laboratory, covers a survey of the extent and nature of losses in commercial stores of Cox's Orange Pippin in relation to orchard factors, and a study of methods of sampling for storage experiments, together with storage experiments with fruit of known cultural history from the experimental plantations on the Research Station and from commercial plantations.

In the year under review a small-scale beginning was made with an experiment upon Laxton's Superb apples from a soil management trial. Indications were found that differences in behaviour in storage at 38° F. as regards wilting and fungal rots could be correlated with soil treatment ; the apples from trees under grass stored better than those from trees under arable or straw mulch on this occasion.

In 1953-54 some additional staff became available and a wider range of experiments was undertaken, involving over 100 separate samples of apples, mainly Cox's Orange Pippin. Chemical and physiological determinations are in the main being concentrated on apples from the large manurial trial at the Research Station. This, as stated earlier, has been developed to include a sward treatment and will provide comparable fruit grown under a very wide range of cultural conditions (see page 25).

Part III

RESEARCH REPORTS AND REVIEWS

AMOS MEMORIAL LECTURE*

SOME ASPECTS OF GROWTH AND DEVELOPMENT IN THE FRUIT PLANT

By Professor R. H. STOUGHTON, D.Sc., A.R.C.S.

The outstanding characteristic of Jesse Amos, to which earlier speakers in this series of lectures have so often referred, was his understanding of the plant. This understanding came about from his keenness of observation, his long experience of the fruit plant, and his powers of logical deduction. In his time, the application of science to fruit growing was still in its infancy, and he was one of the chief nourishers of that sturdy child. Plant pathology, biochemistry, and physiology, sciences which were already well developed as laboratory studies, had not then more than begun to solve the problems of the fruitgrower. Since the time, forty years ago, when Amos went to East Malling as assistant to its first Director, Captain Wellington, very remarkable progress has been made in each of these fields.

But even yet we are far from that deeper understanding of the plant upon which progress in the application of horticultural science so vitally depends : the understanding of how the organism works, what ‘ makes the wheels go round ’. It is the special function of plant physiology to attempt the solution of this problem and it is with certain aspects of it that I have been asked to deal in this lecture.

Perhaps it is because I am myself a plant physiologist, that the subject seems to me to occupy an important co-ordinating role in the biological sciences. In the study of its problems physiology calls upon, and links together, all those fields of knowledge whose boundaries embrace some portion of the world of living things : chemistry, physics, meteorology, mathematics, and even geology. In our attempt to understand how living things work we must study the chemical substances of which they are made, the way in which the organism obtains or manufactures these substances, their movement from one part of the body to another, and the transformations which they undergo. At the same time it is necessary to examine the effect that any or all of the physical conditions of the environment, temperature, humidity, light, and so on, may have upon these diverse processes.

But this type of study, essential though it is, will alone never give us the answer to our foremost problem, the *behaviour* of the organism. It is not sufficient, for example, to know how a plant manufactures sugars and how it transports them to particular regions of its body ; for a proper understanding of the working of the plant we must find out why these observed phenomena result in some particular growth or flowering response. The ultimate aim of applied physiology is *control*, control over the behaviour of the plant to enable us to direct that behaviour along the paths most beneficial to the grower and to the consumer of his products.

Sir Edward Salisbury, in the third Memorial Lecture, drew attention to the point that what constitutes a healthy, profitable plant to the grower is not necessarily a plant which under natural conditions of growth would be best fitted to survive—the biologist’s usual test of fitness of an organism. In his own words, ‘ what we regard as desirable does not correspond to what is healthy, considered as organism under natural conditions ’.

The applied physiologist is concerned, then, with gaining such an understanding of the growth processes of the plant that he may control them to produce that ‘ artificial ’ result desired by the grower. In the particular case of fruitgrowing this involves an understanding of the processes leading to reproduction in the plant and the factors which influence that reproduction. Fundamentally all other problems are subsidiary to this, since the primary object of the grower is, and must be, to produce more fruit of better quality for less cost, and the first essential, therefore, must be control over the reproductive processes of the plant, because, if he does not get fruit bud formation and flowering, he gets no fruit.

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* The sixth Amos Memorial Lecture, delivered at Wye College on 12th November, 1953.

In the first of these Amos Memorial Lectures, the inaugural lecturer, Captain Wellington, stated this and gave as the first and major research problem in fruit growing ' the causes affecting and the conditions influencing the differentiation of fruit buds from growth buds, and their ultimate flowering and the production of fruit '. He went on to say that our knowledge of this problem was very limited and it has not, I think, advanced very much further in the time which has elapsed, so far, at least, as tree fruits are concerned. I hope to show that with other plants, notably the strawberry, research has already contributed greatly to our knowledge since that time.

In choosing the title of this lecture I have deliberately used the terms ' growth ' and ' development ' in contrast to one another, because I feel that the distinction between these two aspects of plant behaviour should be emphasized. I hold that it is one of the major and most valuable concepts which has emerged in plant physiological theory, worthy in importance to rank with the hormone concept, with which, indeed, it is so intimately associated. This is perhaps a bold statement to make, but, nevertheless, I think it is true. I would ask your indulgence for a few moments to make clear the essential difference in meaning which is understood by these two words.

Growth, which is, after all, the fundamental characteristic of living organisms, is surprisingly difficult to define with absolute precision, but it is essentially an increase in magnitude associated with irreversible changes in form. That is perhaps an over-simplification of definition, but I think it will serve our purpose here. The point I wish to make is that basically growth is quantitative in nature, that is, it is susceptible of measurement in terms of some definite unit or units. Development on the other hand implies a qualitative change, the occurrence of which within the plant can only be inferred from some subsequent change in behaviour rather than in a measurable alteration in size such as characterizes growth. A striking example of such a developmental change is shown by the transition from the juvenile type of growth of, say, an apple seedling to the mature form of the young tree. In this case the transition is marked by a more or less abrupt alteration of leaf form, and it is a reasonable inference that some qualitative change has occurred within the plant, resulting in a changed mode of differentiation of the leaf primordia in the bud.

The most familiar example of developmental change in plants, however, is the transition from the vegetative state, the state in which the plant is making growth, to the reproductive state, and it is this transition which is commonly understood by plant physiologists when they use the term ' development ' without qualification. Of such obvious importance is this phenomenon that it has engaged the attention of physiologists all over the world, and a whole new science of developmental physiology has grown up, which has made some remarkable progress in the last twenty years.

Because of their simpler life-cycle, annual plants have naturally been the main experimental subjects in this new science. The successive annual cycles of vegetative growth, flowering, fruiting, dormancy, and then renewed growth again, which are characteristic of deciduous perennial plants, very greatly complicate an already difficult problem and I think that this, in part at any rate, explains why so relatively little work has been done on the developmental physiology of fruit plants. In addition, their comparatively large size involves much more extensive equipment, especially for studies on plants under controlled environments. This factor of size is undoubtedly the reason why we know so much more about the developmental physiology of the strawberry than of, for example, the black currant or the apple.

Many different approaches have been made to this problem of development. Different workers have studied the relationship to flowering behaviour of such factors as the organic metabolism of the plant, its inorganic nutrition, the climatic environment—including temperature, moisture, light intensity, and daylength—the application of synthetic growth substances, and even exposure to x-rays, neutrons, or other kinds of radiation.

That much overworked analogy of the jigsaw puzzle seems peculiarly apt just here. Each of the various factors studied in relation to the development of the plant has resulted in the emergence of a section of a picture. Very slowly different groups of pieces have become enlarged and here and there have met. We cannot, as yet, see the whole picture or know just what is going to show, but it seems that there is emerging a suggestion of the whole, and many workers think that they can discern, perhaps somewhat dimly, a central piece in the composition, though the precise form and character of that central piece still elude us.

It is clearly impossible in a single lecture to attempt to deal with more than a small part of this extensive picture. I intend, therefore, to confine myself at first to one group of pieces which for some reason has lately been somewhat neglected and to try to suggest its possible links with the central figure. Of that figure I can give only a tentative and hypothetical outline, but one which may perhaps serve to focus attention for a moment.

In 1918, two American plant physiologists, Kraus and Kraybill, started a fire of research which blazed furiously for some years, and then slowly died down, though with occasional bursts of new energy ; now it can hardly be said to do more than smoulder. As an outcome of their work on tomato plants grown under different environments, Kraus and Kraybill propounded the theory that growth and fruiting behaviour are conditioned by the quantitative relations between carbohydrates and nitrogenous substances in the plant. According to that theory maximum fruitfulness depends upon a high ratio of carbohydrate to nitrogen and maximum vegetative growth upon a low ratio, provided that neither carbohydrate supply nor nitrogen is in itself a limiting factor, and provided that the plant is growing reasonably satisfactorily.

Now this was at the time an entirely new concept, and research workers everywhere took up the study of what became known as the ' carbon-nitrogen ratio ', and tried to define mathematical ratios which would determine the growth and behaviour of many different plants. It is easy to be wise after the event, and we can see now why so much of this work failed to give the expected answer. How, for example, can one determine with certainty which of the many carbohydrates in a plant are metabolically active and therefore to be used as criteria of carbohydrate content ? There is at present no answer to this question ; still less can we answer it in the case of such labile substances as the organic nitrogenous materials.

In the light of recent plant physiological research, however, it would seem that an even more cogent reason for the failure of the theory was that it put the cart before the horse. The theory sought to explain flowering by a causal relationship of the carbohydrate/nitrogen ratio ; more recent work suggests that, while a relationship in many cases does in fact exist, it may be the flowering itself which is the cause of the observed ratio, or, alternatively, that both may be the result of some common cause.

As so often happens in scientific research, the failure of a theory puts the work itself into disrepute and much of that work, which was very valuable, was forgotten or neglected because it did not fit the theory or give the expected answer. Re-examination of some of the data in the light of later work suggests lines of approach which might profitably be followed up even today. One of these lines is the study of the seasonal cycles of the important carbohydrate compounds and nitrogenous substances of the plant and their relation to growth and development. During the years between the two wars a relatively huge mass of information was collected on this particular subject, especially with reference to the apple tree ; but with the virtual death of the carbohydrate-nitrogen theory and the rise of the hormone concept of plant development, interest in these cycles waned and relatively little new work has appeared in the last decade.

Yet, even if these past studies throw no direct light on the causes of developmental changes, it would seem that they are of interest in their relation to growth and plant management and I will try, however inadequately, to suggest how their further examination might even be profitable in relation to the central problem of flowering.

Let us first consider the carbohydrate compounds found in the plant, particularly in the apple tree, their distribution in the various tissues, and the seasonal cycles which they undergo. Of the simpler carbohydrates or sugars, the reducing sugars glucose and fructose, and the disaccharide sugar sucrose are, to the best of our present knowledge, the most important in metabolism. Pentose and similar simple sugars of that type rarely, if ever, occur in the free state, but in the complex or associated carbohydrates, such as the hemicelluloses and the gums, they do become notable constituents of the tissues. The polysaccharide starch—or more correctly starches—some of the major temporary or permanent storage materials, have always received close study as an index of the carbohydrate status of the tissues, but there is good reason to believe that storage material is a less good criterion than was at one time supposed. The structural carbohydrates, such as the celluloses and lignins, have received a good deal of attention in past studies, but they would seem to be of less moment in our present discussion.

The most complete study of the distribution of these main groups throughout the entire tree has been carried out by Murneek in America, who analysed all parts of 18-year-old trees of three varieties uprooted in the autumn. While the varieties showed differences in detail, the general picture was substantially the same in all of them.

The trees weighed between 850 and 1,000 pounds, of which 20-30 per cent comprised the roots. Some 30 per cent of the dry weight of the above-ground parts of the tree and some 40 per cent of the roots represented the so-called ' available ' carbohydrates—hemicelluloses, starches, and sugars. The branches contained 20-25 per cent of hemicelluloses and something like 5-6 per cent each of starches and sugars, but the roots were usually notably richer in starch (up to 18 per cent) and in sugars, with correspondingly smaller amounts of hemicelluloses. Hemicelluloses are characteristically storage products within the above-ground parts of the plant.

At the time of year when the analyses were made by Murneek, that is, shortly before leaf-fall, much of the carbohydrate normally present in the leaves had disappeared, only some 25 per cent of the dry weight being represented by hemicelluloses, starches, and sugars. The highest concentration was found, as might be expected, in the younger parts—the spurs, young shoots, and the younger roots. The older parts of the tree, composed largely of structural materials, showed markedly lower concentrations ; these are expressed in terms of concentration as a percentage of the total weight.

Looked at from a different angle, however, that of actual total amounts of available carbohydrate, the picture is reversed. The older parts of the tree, because of their greater total mass, possessed by far the larger quantities and would appear, therefore, to serve as the storage reservoirs of these materials. This viewpoint, of the total quantity of storage material available rather than of its relative concentration, is one which is not always adequately appreciated by workers on the chemical composition of plants. When we remember the ease and speed with which labile materials of this nature are mobilized at points where they are needed for growth in the plant, it is surely the total amount ultimately available for these needs which is primarily important, rather than the local concentration at a given moment.

At the beginning of winter, then, the younger parts of the tree are rich in storage carbohydrates, mainly hemicellulose and starch, while a relatively massive reserve, though at a lower actual concentration, is stored up in the older parts of the trunk and branches, and in the roots ; that gives us the picture, then, at the beginning of the rest or dormant period of the plant.

For information on the later cycles of the principal materials throughout the season we may look particularly to the work of Dr. Elsie Smyth, now Mrs. Tom Wallace. During the winter the most notable change that takes place is a fall in starch and hemicelluloses and a corresponding rise in sugars, especially reducing sugars. The evidence is strong that this change over from a high concentration of hemicelluloses and starch to a high concentration of sugar is due to the fall in temperature during the winter, the starch-sugar and hemicellulose-sugar equilibria being temperature-conditioned and tending towards hydrolysis at lower temperatures. Starches and hemicelluloses therefore decline to a minimum in January-February, the coldest part of the winter, and then, with the rise in seasonal temperature, the equilibrium is altered in the opposite direction, and they show an increase to a second maximum before bud-break. In passing, it is worth noting that this increase in soluble sugars during the coldest part of the winter serves as some measure of frost-protection, since the higher concentration of the cell-sap entails a somewhat lower freezing point, and at the same time has a certain degree of protective action upon the colloids of the protoplasm.

At bud-break, then, there is a high concentration of total carbohydrates, especially starches and hemicelluloses, in the bark of the younger shoots, in the regions, that is, where growth is about to start. As the leaves unfold and extension growth begins, there is a heavy demand for carbohydrates in the new growth and this is reflected in a rapid depletion, especially in the wood. Sucrose and starch fall to a minimum quickly, but the early minimum of reducing sugars, which is reached at the same time, is followed fairly rapidly by a rise as the leaves unfold and start to manufacture sugar. When the period of full growth in summer is reached, the utilization of sugars in a vigorous tree tends to exceed the rate of their manufacture and all carbohydrates, with one exception, show a marked decrease in amount. The exception is hemicellulose, which even during that period of maximum demand upon the carbohydrates of the tree may, and usually does, show some increase in the wood. It would seem, though we need much more work on the subject, that this substance, or complex of substances, plays a steadying role in the carbohydrate metabolism of the tree, serving as a reservoir which helps to avoid too great a drain on the total reserves of the plant.

With the slowing down of growth in late summer and the achievement of full leaf-area, the rate of utilization of carbohydrates becomes less than the rate of their manufacture and a rapid increase in all forms occurs in September. As the leaves age there is a rapid transport back from them of still more carbohydrates and the maximum in the younger permanent parts of the tree is once again reached at the time of leaf-fall. That then gives us some picture in the back of our minds of the cycle of these substances in the apple.

In the strawberry plant, and I mention the strawberry because I am going to come back to it later on, Long and Murneek have shown that the seasonal cycles are very similar in general form to those I have outlined for the apple. The earlier period of vigorous growth in the strawberry, however, leads to an earlier decline in carbohydrate reserves, while runner production throughout the summer delays the later accumulation of carbohydrates, so that the period of low carbohydrate reserves is more prolonged than in the apple.

Before considering the possible relation of these metabolic cycles to the developmental cycle, let me turn very briefly to the corresponding changes in the nitrogenous compounds.

Murneek, again, has shown that, as with the carbohydrates, the great bulk of the storage nitrogen in apple trees is contained in the older parts of the plant, though the actual concentration as a percentage of the dry weight is lower than in the younger tissues. His evidence suggests that there is a marked uptake of nitrogen from the soil in the autumn, and that much of this is stored in the young roots throughout the winter awaiting translocation to the growing regions in the spring. Total nitrogen is low towards the end of winter and most of it is in the form of protein. Karmarkar, in studies parallel to those of Dr. Smyth, found a rapid increase in June in all forms of nitrogen, especially the simpler forms, associated presumably with spring root-growth and the absorption of nitrogen from the soil. This high maximum in the middle of summer is followed by an equally steep fall in later summer with a somewhat variable and irregular rise again in the autumn, partly due to root uptake as Murneek has suggested and partly to translocation back into the stem of nitrogen from the ageing leaves.

This account of the seasonal cycles is obviously generalized and takes no account of the shorter-term changes, though it is more than possible that they may be of considerable importance in relation to the seasonal developmental cycle. It is just because of the uncertainty about the local and short-term changes that further detailed study would appear to be justified.

One important study of such local changes, however, must be briefly referred to, that by Hooker of the seasonal cycles in the spurs. Hooker, of course, is not by any means the only one who has worked on this problem, but I take his work as illustrating well the kind of thing that happens. He showed that in bearing spurs the starch minimum reached in early summer lasts for a longer period than in non-bearing spurs. In the latter, the minimum attributable to the great demand by the young growing leaves is soon followed by a quick rise as the leaves become functional, so that during mid-summer the starch content of the tissues is relatively high. In the bearing spurs, however, the growing fruit imposes a steady drain on the available carbohydrate and delays accumulation during the middle of the summer period. It is, of course, well known as a result of work at Long Ashton and East Malling that individual spurs of biennial bearing varieties are normally biennial, in fact the biennial bearing of the tree is due to the biennial bearing of the spurs, and it is this kind of evidence which was formerly adduced to support the theory that a high carbohydrate-nitrogen ratio was the cause of fruit bud differentiation. These workers have shown, however, that the number and size of the leaves and, therefore, the photosynthetic area on non-bearing spurs, is greater than on spurs carrying fruits, and this alone would account for the earlier accumulation of starch. It might also, as I shall endeavour to explain, possibly account for the greater tendency to fruit bud rather than wood bud differentiation through an entirely different mechanism. If that is so, then carbohydrate accumulation in the non-bearing spur might have only a fortuitous association with fruit bud differentiation, though, in point of fact, other evidence suggests that the connection may be somewhat closer.

So far I have dealt solely with the carbohydrate/nitrogen aspects of this problem. May we now, for the time being, leave this carbohydrate and nitrogen story in the plant, and turn for a while to certain aspects of the developmental picture, returning later to see if we can in any way relate the facts we have so far considered to the phenomena of flowering.

Now, it is a familiar fact that, in annual plants at any rate, the initiation of flower buds is largely controlled by the environmental factors of day length and temperature. Very recently the relationship of these two factors to flowering was the subject of another memorial lecture—the Masters Memorial Lecture of the Royal Horticultural Society—by Professor F. G. Gregory. I will not, therefore, weary you with a repetition of the evidence so admirably summarized there, but, as Professor Gregory in his lecture did not refer to fruit, some amplification of the story in this respect may perhaps be justified.

Earlier in this talk I emphasized that the developmental change involved in flower initiation is of a qualitative nature. Klebs, the great German plant physiologist, in his classic work on *Sempervivum*, was the first to recognize this qualitative change, which he called the attainment of ' ripeness to flower '. Until this stage was reached, which involved in *Sempervivum* the attainment of a critical size of rosette, no treatment of any kind was effective in inducing flowering. The attainment of ' ripeness to flower ' has been likened by Gregory and others to puberty in the higher animals, the achievement of sexual maturity before which reproduction is impossible. The critical size which must be reached varies greatly from plant to plant and there is evidence which suggests that ' ripeness to flower ' can be achieved even immediately after germination before any appreciable amount of growth has taken place. It is more probable, however, that Gregory's theory of a ' minimal leaf number ' is valid, that is, that for any particular species or variety a certain invariable minimum number of leaf primordia must be initiated by the stem apex before the change over to flower formation can begin.

In the perennial plant the problem is obviously much more complex, and less evidence is available on which to formulate theories. The characteristic feature in the perennial higher plant is the successional cycle of growth, flowering, fruiting, dormancy and then renewed growth again. It is not clear whether the stage of ' ripeness to flower ' can be achieved once and for all in the growth of the perennial plant or whether in each seasonal cycle the new growth has to attain a minimal leaf number before flower initiation can begin. The phenomenon of 'juvenility' to which I have already referred might suggest that in such cases at least attainment of the adult state is synonymous with puberty. On the other hand, some of the extensive amount of work which has been done on the chrysanthemum, the carnation, and some other perennial plants, seems to indicate that a certain amount of growth in each shoot must be made or, alternatively on Gregory's hypothesis, a minimal number of leaves must be initiated by the stem apex before the change to flower initiation can take place. It is possible, of course, that perennial plants differ from one another in this respect, and that in some puberty is attained once only, whereas in others it is repeated annually in each cycle of new growth.

If the change from 'juvenile' to 'adult' form of growth is ever identical with the attainment of puberty or 'ripeness to flower', then one complication is removed from the study of development in such plants. The conclusive determination of this point would seem to be a promising field of research.

But the attainment of 'puberty' is far from being the end of the story. It is after this phase has been reached that the influence of such factors as day length, temperature, and the metabolic condition of the plant becomes apparent.

First let me recapitulate the salient points with regard to the effect of day length on flowering, the phenomenon known as photoperiodism. Plants fall into three major categories: first, short-day plants which have a critical dark period which must be exceeded if flowering is to occur; they might, therefore, more correctly be called long-night plants. Secondly, long-day plants which, in contrast to short-day plants, have a critical dark period which must *not* be exceeded; these cannot, however, strictly be called short-night plants because, at least in many cases, there is a critical minimum light period required for flower initiation. Thirdly, day length-indifferent plants are those which can flower under any day length provided the temperature and light intensity are adequate. Plants belonging to this group, which have large stores of reserve foods, such as potato or bulbous plants, are able to flower in complete darkness.

In passing I would just mention that it is possible, in fact, in the view of many people it is becoming probable, that there is no such thing as a truly day length-indifferent plant, and it is only necessary to find the right conditions for such day length-indifferent plants to fall into one or other of the two major categories.

In certain plants photoperiodic induction is possible, that is, after exposure to a certain number of cycles conducive to flower initiation, flowering will begin and will continue even after transference to an unfavourable environment.

In short-day plants the critical dark period must be continuous to be effective; very short exposure to light, even of a few minutes' duration, during the dark period, may be sufficient to prevent flowering.

Within the critical range of day lengths the effects of successive cycles are, in many cases, additive, that is, the number of flower initials laid down is roughly proportional to the number of inductive cycles given.

The final point I would make in this summary is that the perceptive organ for the photoperiodic stimulus is the leaf. Leaves exposed to non-inductive cycles can inhibit the effect of other leaves on the same plant which have received inductive cycles if the former are situated between the latter and the differentiating meristem.

Gregory has propounded a theory to explain the mechanism of the photoperiodic reaction in short-day plants; very briefly, it is that in the darkened leaf a substance, or hormone, is produced from a precursor and is transmitted to the growing points where it leads to flower initiation. The formation of this hormone takes a certain length of time, and this accounts for the minimal dark period required; interruption of the dark period will stop and perhaps reverse its formation. In light the reactions leading to the formation of the flower-forming hormone are altered and the precursor is converted into a leaf-forming instead of a flower-forming hormone. Leaves on the same plant exposed to non-inductive cycles produce this leaf-forming hormone, which can override or inhibit the action of the flower-inducing hormone if the two substances meet on the way to the growing point.

I have given a bald and over-simplified summary of the facts and theory of photoperiodism because this is not the place, as I have said, for a more extensive review. These facts are, however, essential to my further discussion, but it should also be emphasized that they relate primarily to the behaviour of annual plants, though such evidence as we have for perennial plants does indicate a general similarity of behaviour.

I must now turn equally briefly to the complicating factor of the influence of temperature on flower initiation and its interrelations with the photoperiodic response. Here again most of the research work has been done on annuals, especially cereals, in which the phenomenon of vernalization is of very great theoretical and practical importance.

Temperature effects may be of two kinds : immediate effects, in which the ambient temperature at the time influences the initiation process, and after effects, in which the response is shown only after a considerable lapse of time during which changes in temperature may be relatively unimportant. Vernalization is the term usually given to this latter phenomenon.

Temperature, of course, affects all plant processes greatly and flower formation may be directly influenced by the prevailing temperature at the time when it is occurring. Indeed, in some cases flower initiation is inhibited completely at temperatures above or below a certain critical range. This is the case, for example, in many bulbous plants, notably the hyacinth. Even where there is no sharply delimited range, temperature may modify the speed or degree of flower formation.

But what, for this discussion, is of even greater importance is that temperature may modify the photoperiodic response. Thus, at high temperatures a plant may be markedly photoperiodic and flower only in short days, whilst at low temperatures day length may have a much reduced effect or even none at all. In other cases, temperature may operate in the reverse way and the plant may show a response to day length only at low and not at high temperatures.

The phenomenon of vernalization is different from either of these relatively direct effects. The essence of the theory of vernalization is that exposure to a temperature within a critical range (a low temperature in the case of most short-day plants) is necessary before the plant can attain the condition of ' ripeness to flower '. Lysenko, the Russian plant physiologist, claimed that this requirement was absolute and irreversible and must be satisfied before the photoperiodic stimulus could be effective. In his terminology, the ' thermo-phase ' must be completed before the ' photo-phase ' can begin. Gregory and his co-workers have shown that, in cereals at least, not only is vernalization by low temperature sometimes reversible by subsequent high temperature treatment, but also that vernalization may to some extent be achieved by day length modification alone.

The same workers have demonstrated that the vernalizing effect of low temperature is not upon the leaf, but upon the growing point itself. This is in sharp contrast to the photoperiodic mechanism where, as we have seen, the influence is upon the leaf, and it suggests that a different complex of chemical reactions is involved in the two phenomena.

The conception of vernalization has been applied in only a few cases to perennial plants as, for instance, in the chrysanthemum, a short-day plant, for which Schwabe, of the Imperial College, has claimed that exposure to a low temperature is essential before short days can induce flower initiation. This low temperature vernalization, he states, can be applied effectively to the parent plant during the winter so that cuttings or shoots produced later on the plant are already vernalized and can initiate flowers in short days. It has been shown by Dr. Vince at Reading, however, that some varieties of chrysanthemum, at least, do not require this low-temperature vernalization, but can initiate flowers even at continuous high temperatures in short days, though long days will inhibit or greatly delay flower initiation. There is evidence in the case of the carnation also that the previous temperature history may modify the subsequent flowering behaviour.

Turning again to fruit, here we are on less sound ground, because we have little experimental data on all these questions of the effect of the environment on flowering. The strawberry is the only fruit plant on which any extensive studies of this type have been made, and I will attempt to summarize briefly the present state of our knowledge concerning its flowering behaviour.

The summer-fruiting strawberry, which is the type normally grown in this country, is what is known as a facultative short-day plant, that is, inflorescences are normally formed under short days, but under certain circumstances the plant will form flower buds under longer days. Guttridge, working with me at Reading on the varieties Royal Sovereign and Auchincruive Climax, has shown that Sovereign starts to initiate its flowers in the shortening days of early September, but that Climax, which is less sensitive to day length, begins to do so in late June or early July. It is these early-formed inflorescences in Climax which emerge and flower in autumn and produce the late crop characteristic of this variety. The later-formed flower buds of both varieties, that is, those formed in September, normally remain within the crown-bud until spring when they also emerge and produce the summer crop.

Under outdoor conditions the plant passes into a state of rest or dormancy during the early winter ; this is a true dormancy and not merely a cessation of growth due to unfavourable growing conditions, since plants in this state do not at once resume vigorous growth on exposure to warmth. The onset of dormancy can, however, be prevented by exposing the plant to warm temperatures and long days, and in this respect the strawberry appears to differ from, for example, the apple which loses its leaves and becomes dormant for a period even if kept throughout in warmth, though the effect of long days in this case is unknown.

Coming back to the strawberry, axillary buds below the terminal inflorescence develop into either stolons (runners) or branch crowns depending mainly upon day length, long days promoting stolon formation. Hence, during the early summer the stem axis consists of a vegetative crown-bud with stolon buds and branch crown-buds below it. The subsequent growth of the branch crown-buds appears to depend largely upon the general vigour and, therefore, upon the photosynthetic rate of the plant.

The stolon or runner buds are formed in increasing numbers with increasing day length and grow out with the characteristic long internodes. With the shortening days of autumn, runner formation again stops and the branch crowns of the parent plant and the main axes of the runner plants once more differentiate inflorescences.

It is of interest to note that flower initiation does not occur in the spring despite the short day length at that time of year. Why it does not occur then, but does in the short days of autumn, is one of the puzzles Guttridge has been working on at Reading. Work on the effect of day length and temperature during the dormant period suggests that one of two related hypotheses might explain this seeming paradox. Guttridge himself inclines to the theory that the low temperatures of winter cause a decreased sensitivity to short photoperiods, and that the sensitivity is further decreased relative to that in late summer by the small leaf area in spring, remembering, of course, that the leaves are the source of the flower-forming hormone.

An alternative hypothesis, which I propose to elaborate in a moment, is that during the dormant period reserve carbohydrates are depleted by respiration and that this results in either a lesser production of the flower-forming hormone, or a reduced response at the stem apex to hormone which has in fact been formed in the leaves.

It is obvious why the strawberry, with its compact and small habit of growth, has received far more attention than the tree fruits from workers on environmental factors. We know little or nothing concerning the influence of varying day length on apples or pears, since, largely because of mere size, the equipment for such studies must necessarily be large and expensive. We are hoping at Reading to begin such studies on young apple trees now that we have equipment which will permit of at any rate a limited investigation.

Theories of development in tree fruits have been based largely on inferences drawn from their behaviour in different latitudes and climates. The fact that the apple normally forms its fruit buds in June and July suggests at once that long days are needed for flower initiation. Against this, however, is the fact that at high altitudes near the Equator apples and pears still flower, though perhaps less freely, under day lengths which never exceed 13 hours. This fact does not, of course, preclude the possibility that the critical day length may be somewhat less than 13 hours and yet the apple or pear be truly a long-day plant. However, the limiting factor for top fruit production in the tropics is apparently not day length, but the requirement for a certain minimum exposure to low temperatures to enable the tree to pass successfully through the dormant phase and then resume vigorous growth.

Fruitgrowers are aware that there is a certain degree of apparent antagonism between vegetative growth and fruitfulness. Trees growing over-vigorously either do not flower or do so only sparsely. Lees, at Long Ashton, showed also, many years ago, that flower bud differentiation in any year depended largely upon the crop and weather conditions in that year. Large crops, which make a heavy demand on stored reserve foods, or dull, wet summer weather, which reduces accumulation of reserve foods, result in less fruit bud formation for the following year's crop.

These observations and the facts which I outlined earlier with regard to the carbohydrate status of bearing and non-bearing spurs in biennial bearing varieties naturally have suggested in the past that fruit bud formation was a result of carbohydrate accumulation. Yet all the work of photoperiodism in annual plants indicates that there is in fact no causal relationship between carbohydrate or nitrogen status and flowering.

The development of the hormone concept of flowering opens up new lines of thought and suggests possible ways in which these apparent contradictions *might* be reconciled.

May it not be that the flower-forming hormone produced in the leaves under favourable day length requires for its action upon the growing point a certain nutritional status in the tissues? We have seen that temperature, for instance, can exert a profound effect upon the growing point, modifying the influence of the flower hormone and in some cases inhibiting its action. We have seen, also, that temperature has a controlling influence upon the starch-sugar and hemicellulose-sugar equilibria in the tissues. It could be that the carbohydrate status may be a modifying factor in the action of hormones upon the differentiating meristem. There can be no doubt of the complexity of the hormone mechanism, and it is at least possible that this mechanism involves the primary metabolic substances such as the sugars.

If some such hypothesis be valid we can see that, while the carbohydrate and nitrogen status would have no causal relation to flowering, nevertheless environmental conditions controlling the primary hormonal mechanism might have simultaneous influences upon the carbohydrate equilibria, modifying the subsequent response at the stem apex.

The association suggested between the hormonal mechanism and carbohydrate would indicate that the management of tree growth should aim at conditions favouring carbohydrate accumulation in the neighbourhood of the differentiating bud. Maximum leaf area near the bud would be expected to favour flower initiation by increasing both hormone formation and carbohydrate synthesis. Conditions leading to early slowing down of growth rate in shoots and spurs, by reducing the rate of carbohydrate utilization, would be expected also to help towards flower bud initiation. These circumstances are, in fact, known to be associated with flower bud rather than wood bud formation.

In such a lecture as this it is not possible, nor is it desirable, to enter into experimental detail. I have tried only to bring into relation certain aspects of the growth and the development of plants, simply with the idea of stimulating thought. If I have been guilty of over-simplifying and over-running the evidence I can only plead that scientific progress has often depended upon guesswork followed by critical experimentation.

POMOLOGY

THE SOILS OF EAST MALLING RESEARCH STATION

By B. S. FURNEAUX

INTRODUCTION

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  - Bearsted Series
  - Lowlands Series
- Soils of the Alluvial area in the valleys
  - Bradbourne Series
  - Millhall Series
  - Twisden Series
- Made land

DISCUSSION

SUMMARY OF THE SOIL SERIES AND PHASES

SUMMARY

REFERENCES

INTRODUCTION

A detailed field survey was undertaken in 1951 with the object of contributing to the knowledge of the growing conditions provided by the soils of the Research Station. In the course of it, 542 borings were made and observations recorded in detail. Where the underlying stone permitted, these were made to a depth of 5 ft. 2 in. (158 cm.). In those cases where only a shallow penetration was possible a number of borings were made within a limited radius, so as to establish as true a picture as possible of the conditions obtaining. Where there was nothing to suggest any unusual complexity of soil distribution, the borings were roughly 50 yards apart, but, in many places, their location was determined by the need to establish the form of an individual area of soil.

The account which follows has been drawn up from the observations made. The nature of the parent material, from which the soil has been formed, and the changes the latter has undergone to bring it to its present condition, have a great bearing upon the character of the soil. A brief account is, therefore, given of the geology of the area, followed by descriptions of the soils, together with attempts to assess each soil from the standpoint of a fruit grower.

The author wishes to acknowledge most warmly the invaluable help given throughout the survey by Mr. J. E. Goode, of the East Malling Research Station, who tirelessly shared the not inconsiderable labour of making the borings and who mapped the location of each, as well as offering most helpful suggestions and advice in all stages of the work.

GEOLOGY

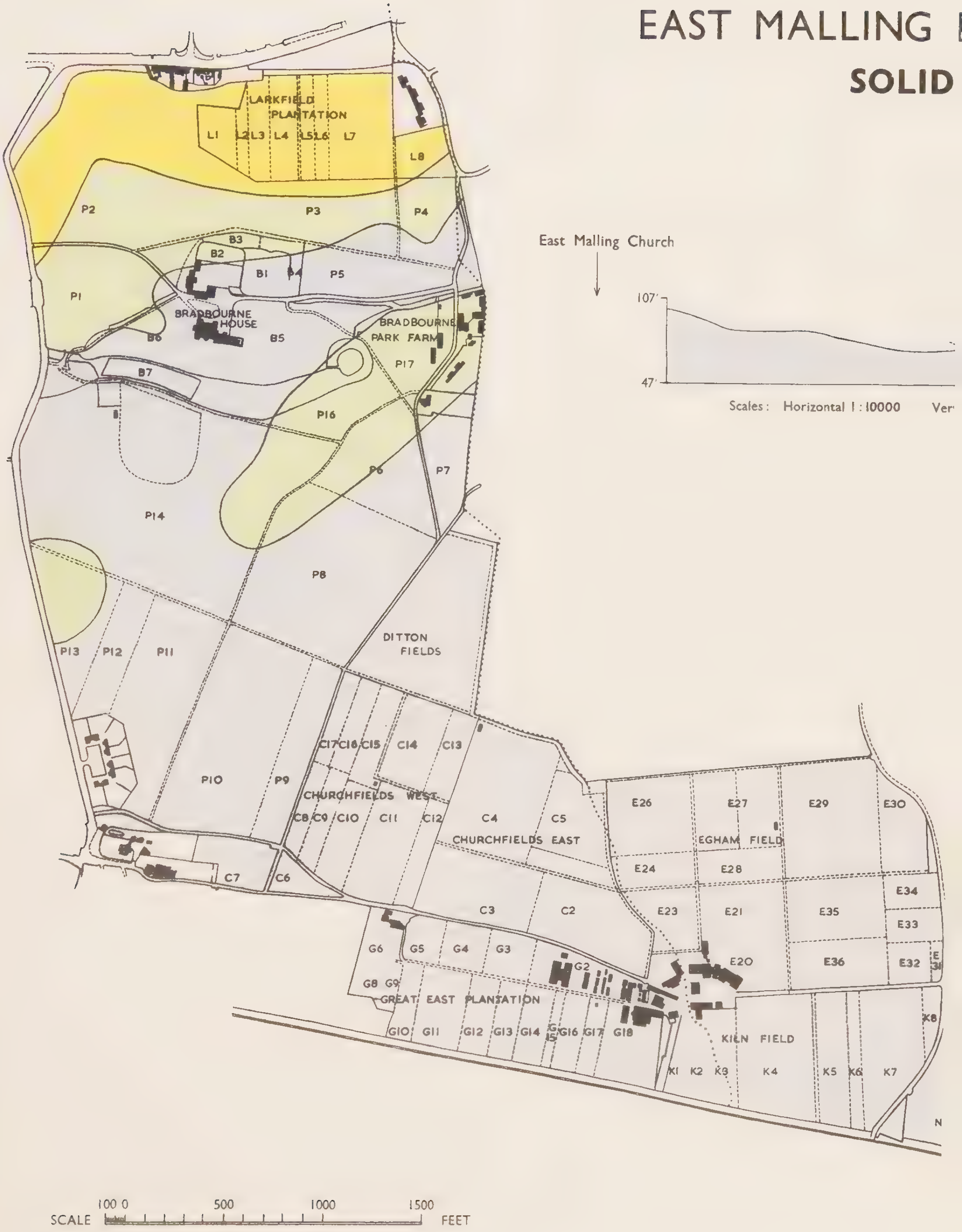
The older rocks.

The Research Station lies on the Lower Greensand, at the point where its outcrop is widest in the whole of the Weald. This formation stretches from east to west, practically the whole length of the counties of Kent and Surrey and, at this point, reaches a breadth of about six and a half miles. The Lower Greensand is the uppermost part of the Lower Cretaceous (Aptian) system and was laid down in shallow sea. Unlike that of the rest of England, the Lower Greensand of the south-east shows a great deal of variety. It is separated into four sub-divisions which occur in the following order, the oldest being at the bottom—

Folkestone Beds
Sandgate Beds
Hythe Beds
Atherfield Clay.

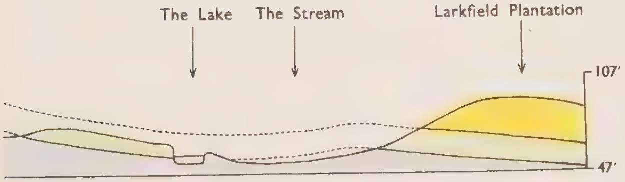
EAST MALLING

SOLID


LARKFIELD PLANTATION
L1
L2
L3
L4
L5
L6
L7
L8
P2
P3
P4
B3
B2
B1
B4
P5
P1
BRADBOURNE HOUSE
B6
B5
BRADBOURNE PARK FARM
P17
B7
P16
P6
P7
P14
P8
DITTON FIELDS
P13
P12
P11
P10
P9
C17
C16
C15
C14
C13
CHURCHFIELDS WEST
C8
C9
C10
C11
C12
C4
C5
CHURCHFIELDS EAST
C7
C6
C3
C2
E26
E27
E29
E30
EGHAM FIELD
E24
E28
E34
E23
E21
E35
E33
E20
E36
E32
G6
G5
G4
G3
G2
G8
G9
GREAT EAST PLANTATION
G10
G11
G12
G13
G14
G15
G16
G17
G18
KILN FIELD
K1
K2
K3
K4
K5
K6
K7
K8
N
East Malling Church
107'
47'
Scales: Horizontal 1:10000 Ver
SCALE
100 0
500
1000
1500
FEET

RESEARCH STATION

GEOLOGY


The Lake
The Stream
Larkfield Plantation
107′
47′

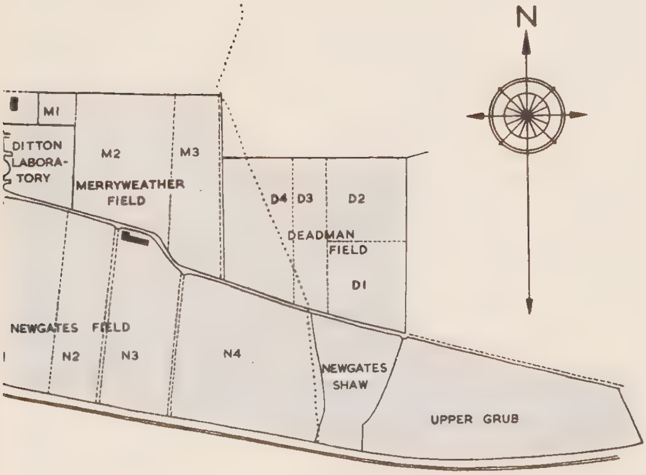
ical 1 : 1440

LOWER GREENSAND

🟨 Folkestone Beds

🟩 Sandgate Beds

⬜ Hythe Beds (Ragstone)


N
M1
DITTON LABORATORY
M2
M3
MERRYWEATHER FIELD
D4
D3
D2
DEADMAN FIELD
D1
NEWGATES FIELD
N2
N3
N4
NEWGATES SHAW
UPPER GRUB

The land of the Research Station extends on to the uppermost three, the Atherfield Clay alone not being represented.

The Hythe Beds, which are also known as the Kentish Rag or Ragstone, consist of alternating seams of hard grey limestone, known as *rag*, and earthy calcareous sand, known as *hassock*. The strata vary in thickness from a few inches to about a couple of feet. The rag is a crystalline limestone, but it contains a good deal of sand grains, chiefly quartz and glauconite. In some seams the amount of silicious material is sufficient to convert it into a somewhat porous chert. The rag is quarried for road metal just beyond the boundaries of the Research Station and was formerly used extensively for building. The hassock is pale buff to almost white in colour, and varies from an earthy sand to a soft, lime-cemented sandstone. There is often sufficient glauconite present to give the hassock a greenish tinge, which becomes quite bright when its soft grains are smeared when cut with a spade or auger. It is this glauconite, a hydrated silicate of potassium and iron, which gives the Lower Greensand its name, although in many strata its presence is not very obvious.

The Sandgate Beds are usually composed of sandy clay. In colour they are variable, but they generally range from yellowish-brown, with a distinct green tint, to a deep green, often flecked with bright orange. Glauconite is usually plentiful and tends to give the clay a peculiarly sticky texture.

The Folkestone Beds here consist of yellow and brown quartzose sands, generally rather fine grained but often showing a considerable mixture of particle sizes ranging from fine to coarse. A number of the grains are of the grey or black silicious material known as lydian, while glauconite is also present. The colour is, however, due to the presence of limonite, hydrated iron oxide. In places this cements the sand grains together to form irregular seams of hard, dark brown ironstone, known as carstone. The Folkestone Beds are conspicuously false bedded, from the currents which swept the floor of the shallow sea in which they were laid down.

In this district both the Hythe and Folkestone Beds are about 100 feet in thickness, but the Sandgate Beds are much thinner, being little more than 10 feet.

The area is part of the northern half of the Wealden anticline, so the dip of the rocks is gently northwards. Thus, each successive stratum is inclined to the north and vanishes below the one next laid down, which lies on top of it. At this point the outcrop of the Hythe Beds is nearly five miles wide. They present a steep escarpment, rather more than 400 feet above sea level, to the Weald of Kent which lies to the south. From their southern margin they slope steadily downwards towards the north, the highest point on the Station being 176 feet, and reach about 50 feet at the stream at Bradbourne. From this point the land rises on to the Folkestone Beds, which form a range of low hills, breached by the stream itself.

Drift deposits.

This regular northward slope of the ragstone hills is deeply intersected by the valley of the River Medway, which flows in a great curve on three sides. It runs two miles to the south of the Research Station, where it has carved its way right through the Hythe Beds and Atherfield Clay, to the Weald Clay beneath. From here it flows north-eastwards through Maidstone and thence, north-westwards through Aylesford, less than a mile from the Station land.

The present landscape is the handiwork of the Medway and its various tributaries, including that which runs through the Research Station land at Bradbourne. These rivers have sculptured their valleys out of the rocks of the Lower Greensand and, in doing so, have carried away vast quantities of debris from them. A part of this has been left behind—a mixture of materials from all the geological formations of the district—often at some considerable distance from the place where the river now runs. The river, too, has taken long ages to cut its way down to its present level. Thus, many of these drift deposits left by it lie far above its present course, as well as some distance from it. They mark the wanderings of the streams in their earlier days, before the countryside assumed the shape it is to-day. There are indications that the stream which runs from East Malling village to feed the lake at Bradbourne has undergone changes of course within recent historic times, while the lake itself is artificial and lies well above the floor of the valley at its eastern end.

These river drifts are composed largely of the harder materials and coarser fragments of the rocks, from which much of the finer constituents have been washed away. They consist mainly of quartzose sand and lydian from all the Lower Greensand beds, as well as fragments of chert from the Hythe Beds, carstone from the Folkestone Beds, and flints from the nearby chalk. Far less plentiful are fragments of very fine grained sandstone and shale from the Wealden rocks further upstream.

These river gravels are the most important drift deposits of the district. They fall into two distinct classes—those in which the particles are relatively small, so that they consist of sand and fine gravel only, and those in which fairly large stones contribute a considerable proportion of the material.

Both are found at various levels, having been laid down at numerous stages in the development of the landscape.

Associated here and there with the gravel are small stretches of brickearth, a brown loam of mellow texture. This was probably originally wind-blown loess, though some of it may have been carried to its present position by subsequent mud flows and surface washing.

The alluvium alongside the present stream consists not only of river sands and gravels, but also of deposits of highly calcareous material precipitated from the water. The stream is fed by numerous springs, which issue from the limestone rock saturated with calcium bicarbonate. Some of this is precipitated as a calcareous grey silt, but a great deal is formed into concretions up to half an inch in diameter, which form a sort of gravel. These concretions, when split, show concentric rings of growth ; this is a form of tufa.

The ragstone, being a much jointed rock, allows the rain which falls on it to penetrate very freely. In doing so, the carbon dioxide dissolved in it causes the gradual solution of the calcium carbonate in the rock which, of course, is the source of the lime in the spring water referred to above. This steady solution of the ragstone just beneath the surface of the land, leads to the accumulation of the insoluble residues from the rock. Besides the sand and chert fragments, a brown clay is deposited, which possesses the characteristic greasy stickiness that weathering glauconite imparts.

Not only have the older rocks of the Lower Greensand undergone erosion, but, from the moment of their deposition, the far younger drift deposits, too, have been subjected to the effects of the weather. River gravels, brickearths, residues from the ragstone have all had some of their materials washed by rain from the more exposed positions and deposited on the gentler slopes below. This process is still actively in progress, and it is most noticeable that many of the roadways and fences which run across the slopes on the Research Station, even though the slopes be gentle, have soil a foot or more higher on one side than on the other. There are thus eroded patches, where the rock is near the surface, and deep colluvial accumulations. Both have a profound influence upon soil conditions.

Distribution of rocks.

The greater part of the Research Station land lies upon the Hythe Beds, which stretch from four miles south of the laboratories as far as the buildings north of Bradbourne House (see Solid Geology map opposite page 60). The Sandgate Beds appear at the brook, west of the house, and run across the northern part of the walled garden, gradually climbing up the slope, so that the boundary between them and the Hythe Beds, which they overlie, crosses about the middle of P4. Thus Bradbourne House and grounds, the lake, the arboretum, and P5, all lie upon the Hythe Beds, although these are for the most part buried under alluvial sands, gravels, and tufa.

South of the lake, however, there are two outliers or detached areas of Sandgate Beds, which have been cut off from the main block of this formation by the stream, which has carved its valley through it and into the ragstone beneath. Similarly, the outliers themselves were separated from each other by a former stream, which used to run from the village, across the park, towards the house. Its course can be traced by the complicated series of drifts which line its shallow valley. One of these outliers occupies a considerable portion of P13, while the other forms the elongated hillock, which stretches north-eastwards from the corner of P14 and takes in P16 and P17, as well as a part of P6.

The Sandgate Beds disappear on their north side below the Folkestone Beds, which give rise to a strip occupying the northern part of the estate. The boundary cuts across the south-eastern corner of L8 and runs parallel with the southern boundary of Larkfield Plantation, only a few yards below it. On reaching the rising land in P2 it swings south-westward and crosses the road just below the Mount Memorial Gateway.

Distribution of Pleistocene Drifts.

It will be seen that the older Lower Cretaceous rocks have outcrops stretching roughly east and west, that of the Sandgate Beds having been split lengthways by the stream, which has laid beside its bed an assemblage of alluvial deposits. At various periods, brooks and more temporary flows have run down towards the stream from both sides. Thus the general pattern of the Pleistocene and Recent drift deposits, except for those immediately bordering the stream itself, is at right angles to the east-west direction of the Lower Greensand rocks. This leads to a certain degree of complexity in the distribution of the soils.

Over a very large part of the area the older rocks are covered by drifts of varying types and depths ; in fact, little of the land is free from such materials. The gently sloping, southern part of the Ragstone outcrop carries comparatively wide stretches of river gravel of Pleistocene age. This consists chiefly of fine gravel, composed largely of chert and carstone with some flint, mixed with a large proportion of river sand and loamier fractions. In its lowest layers it incorporates, in many places, some of the heavier-textured materials resulting from the solution of the limestone beneath. These deposits stretch right across the highest parts of the Station in Newgates Field, Upper Grub, and beyond, more than 150 feet above the present level of the River Medway.

Similar river gravels cover much of the outcrops of the Sandgate Beds to the north of Bradbourne, so that only in P1 does this strip have the opportunity of giving rise to the soil. Part of the outlier in P13 is similarly buried, but that which runs in front of Park Farm House is relatively free. It also stretches on to the western end of the Folkestone Beds outcrop, but in quite limited areas.

On the higher part of the Folkestone Beds in Larkfield Plantation, however, there is a cap of Pleistocene river gravel of a much coarser type. It is composed mainly of fairly large stones of flint and chert, mixed among coarse and medium sands. It is quite thin, being in most places less than two feet six inches deep, although in one boring it was found to be a little more than four feet. Erosion has carried the flints from this deposit some distance from their original position, and left them mixed in with the surface layer nearby. There is also a smaller cap of similar gravel on the Sandgate Beds outlier south-west of Park Farm House.

Brickearth occurs in a number of places on the Research Station, but there are no very great stretches of it. On the ragstone there is a small valley which runs northwards across the eastern ends of Kiln Field and Egham Field. The floor of this is occupied by a warm brown incompact brickearth loam, three to five feet deep. This generally overlies the ragstone, but in a few places some fine gravel separates them. Various small isolated patches occur on the higher parts of the Station. A rather larger one occurs in P9 and P10, while a still more extensive one occupies a considerable amount of P8 ; here some three to five feet of brickearth loam lies upon a fine river sand. Another overlies river sand and gravel in P14. All these patches coincide with areas of gentler slope. A further area occurs on either side of the Sandgate Beds outlier in P6 and P14, where four to more than five feet of brickearth overlie fine gravel and sand.

At Bradbourne there is a larger area of brickearth stretching across the northern part of P1, up the slight valley in P2, right to the London Road, and across to the boundary of Larkfield Plantation. It overlies the junction of the Sandgate Beds and Folkestone Beds, concealing it beneath three to more than five feet of loam. Further small patches lie upon the Sandgate Beds in P4 and the Folkestone Beds in the valley of L5, buried under about three feet of downwash from the Folkestone Beds higher up the slope.

Distribution of Recent Drifts.

The great bulk of the Recent Drifts are alluvial in origin and lie close to the stream at Bradbourne. A notable exception is the narrow strip of calcareous loam and fine sand, which occupies the small dry valley running down from East Malling village to the lake. This leads down to a large alluvial area, consisting roughly of the north-western half of P14. The greater part of it is composed of a yellowish fine sand, which varies a good deal in the amount of loamy and silty material it contains, and also in the amount of fine gravel. Towards the stream and lake the gravel becomes coarser and more plentiful in patches, and the drift itself more calcareous.

Once across the lake, there is a stretch of alluvial deposits, still mainly overlying the Hythe Beds, and comprising the flat land on which Bradbourne House stands, B1, B2, P5, the south-east corner of P3, and the lower half of P4. This is mainly highly calcareous and varies from fine sands to silts, with areas of tufa, where lime concretions become abundant. The amount of gravel is variable, but it becomes plentiful in a patch at the eastern end of Bradbourne House.

Natural drainage.

Water passes very freely through the fissures in the ragstone and also through the interbedded hassock. In doing so, it enlarges the cracks and gradually dissolves away the rock, producing quite wide cavities and spaces, which fill with material from on top of the rag. Thus, the exposed section in the face of a quarry shows that the ragstone itself possesses a very uneven surface. In one place it may be little more than a foot below the ground, while a yard away it may be covered by several times that depth of soil or drift material.

All the upper slopes of the Hythe Beds, including the drifts that lie upon them, are well drained in consequence. On the lower slopes, however, as one approaches the lake, the water, which ran so freely through the ragstone, begins to make its appearance once more, in a series of small springs seeping out through the drifts which cover the rag and hassock.

In the lower lying land there is a permanent water table in the Hythe Beds and in the alluvial deposits bordering the streams. The natural levels have, however, been greatly altered by the damming up of the brook to form the lake. This is embanked upon part of its north side, so some of the land lies below the level of the water. How much seepage takes place just here is difficult to ascertain. Suffice it to say that nearly all the alluvial land on both sides of the lake is fed by springs or by a permanent water table. All this water is highly charged with lime and leaves a continual deposit of calcareous silt where it runs in the streams.

The Sandgate Beds are for the most part freely draining too, but, here and there, where the sandy clay lies rather more compact, there is slight evidence of slow percolation, particularly in the drifts which lie upon them.

The sandy Folkestone Beds drain very freely, so they, and the drifts which lie upon them, allow water to pass rapidly through, until the Sandgate Beds beneath slow it up. There is evidence of a certain amount of percolation from small springs from these formations, which contributes to the general water table on the north side of the valley in which Bradbourne lies. This water is free from lime.

SOILS

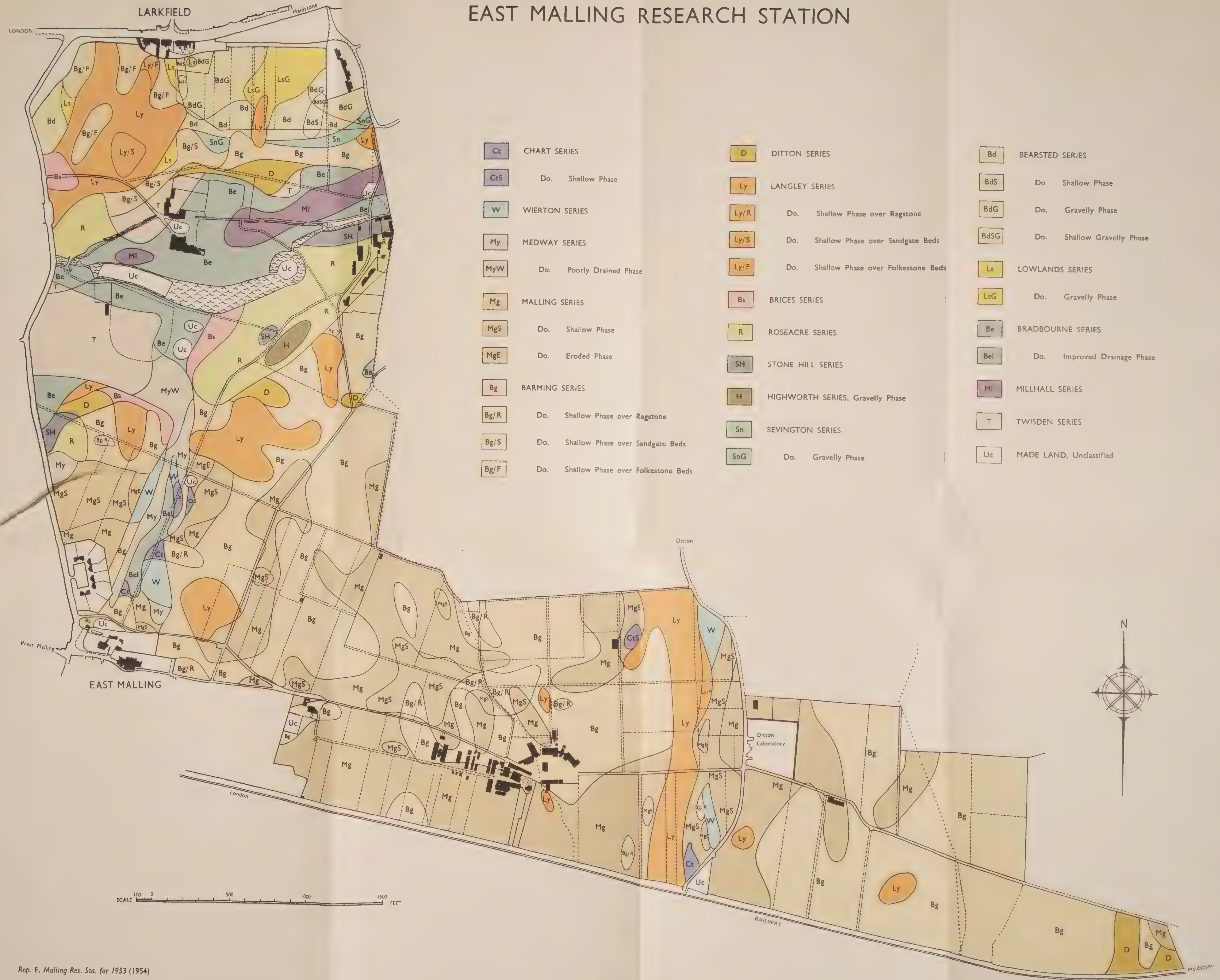
With such a variety of parent materials and such differing histories behind the soils formed from them, such dissimilar drainage conditions and capacities for the retention of moisture, it is hardly surprising that a great variety of soils is to be found on the Research Station. Descriptions of many of them have been published and they have been given names ; a few have not. A number stand out boldly as individuals. ***It is vitally important to bear in mind that whatever system of classification is adopted for anything so infinitely variable as soil, although the typical specimens of each group will exhibit clear-cut distinctions from one another, many groups tend to merge into one another at their margins. The boundaries shown on the soil map are often to be regarded as marking a stage in gradation, not as a line of demarcation between two entirely distinct soils.*** The considerable volume of information available from the detail of the many hundreds of borings carried out is being collated for inclusion in the Station's records.

Thus an attempt is made to present the soils as a number of individuals, each with its own personality, but emphasis must be placed on their relationships with their neighbours. The classification must, therefore, be made to serve the purpose of applying the information rather than becoming its rigid master. The description of each soil must fulfil the dual role of providing a reasonably detailed and intelligible account of its inherent properties and, at the same time, suggesting what sort of environment it is likely to afford fruit trees, which are actually growing or are likely to be planted on it.

Linwood Lee (1931), and Bane and Gethin Jones (1934), have published descriptions of a number of soils on the Lower Greensand. Each employed the International System (Furneaux, 1931 ; Clark, 1941 ; and U.S. Soil Survey Staff, 1951) in which similar soils are grouped into *series* in which the individuals may show slight variations in surface texture. These they separate into different *types* within the same series. Unusual features of depth or shallowness, graveliness or stoniness may be distinguished by sub-dividing the series further into *phases*. Thus, the more important series in the area have fortunately already been named and described. Lee's descriptions are very brief and give little idea of inter-relationships between the various soils, which makes it difficult to apply this naming in some cases. Bane and Jones's descriptions are detailed and easy to apply, but in several cases it would have been desirable to split up some of the series into more than one, as some of them tend to cover too wide a variety of soils. To provide for this, and because of the necessity for differentiating between the various environmental conditions afforded to fruit trees, some of the series have been rather ruthlessly broken down into sub-groupings in the present survey. The distribution of each of these was plotted on a map of a scale of 1 : 2,500 or 25·344 inches to a mile ; a reduced reproduction of this map appears opposite.

In the section which follows, a departure has been made from placing the soil series in the strict geological order of the parent materials, from which they have been formed. Instead, they have been grouped, as far as possible, according to which of the older geological formations they overlie. It is felt that this method will make it easier to trace the relationships which the soils bear to one another. Thus, the Chart Series is derived from the Cretaceous Hythe Beds, and the Barming Series from the Pleistocene valley gravel, yet they are placed close together because between them comes the Malling Series, which is derived from both geological formations and has affinities with the Chart Series on the one hand and the Barming Series on the other. This arrangement is not without its drawbacks because some of the drifts extend over more than one of the sub-divisions of the Lower Greensand. Thus, the Barming Series is found covering all three that occur on the Research Station. So, too, does the Langley Series. It is perhaps rather less convenient from the angle of classification, but more so for following the general narrative.

EAST MALLING RESEARCH STATION


LARKFIELD
LONDON
Maidstone
West Malling
EAST MALLING
Ditton
Ditton Laboratory
London
RAILWAY
Maidstone
N
SCALE
100
0
500
1000
1500
FEET

Ct	CHART SERIES
CtS	Do. Shallow Phase
W	WIERTON SERIES
My	MEDWAY SERIES
MyW	Do. Poorly Drained Phase
Mg	MALLING SERIES
MgS	Do. Shallow Phase
MgE	Do. Eroded Phase
Bg	BARMING SERIES
Bg/R	Do. Shallow Phase over Ragstone
Bg/S	Do. Shallow Phase over Sandgate Beds
Bg/F	Do. Shallow Phase over Folkestone Beds
D	DITTON SERIES
Ly	LANGLEY SERIES
Ly/R	Do. Shallow Phase over Ragstone
Ly/S	Do. Shallow Phase over Sandgate Beds
Ly/F	Do. Shallow Phase over Folkestone Beds
Bs	BRICES SERIES
R	ROSEACRE SERIES
SH	STONE HILL SERIES
H	HIGHWORTH SERIES, Gravelly Phase
Sn	SEVINGTON SERIES
SnG	Do. Gravelly Phase
Bd	BEARSTED SERIES
BdS	Do Shallow Phase
BdG	Do. Gravelly Phase
BdSG	Do. Shallow Gravelly Phase
Ls	LOWLANDS SERIES
LsG	Do. Gravelly Phase
Be	BRADBOURNE SERIES
BeI	Do. Improved Drainage Phase
Ml	MILLHALL SERIES
T	TWISDEN SERIES
Uc	MADE LAND, Unclassified

Rep. E. Malling Res. Sta. for 1953 (1954)

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Soils of the Ragstone area.

Chart Series.

This is a shallow soil derived directly from the weathering of the ragstone and hassock of the Hythe Beds (Lee, 1931 ; Bane and Jones, 1934). It occurs in positions where erosion has prevented the accumulation of weathered materials, so that no great depth of soil could be formed. An important characteristic is that, unlike many of the soils on the ragstone, it is calcareous and, as a result, grey is the more dominant colour. This distinguishes it from those cases where erosion has shallowed soils of the Malling and Barming Series ; in these the dominant colour is brown.

The soil is a medium to heavy loam (silt loam) in texture, and hard grey ragstone is encountered within 30 inches of the surface. Jones gives 24 inches as a maximum depth for this Series, but experience of fruit tree performance suggests that it may be more satisfactory to increase the arbitrary limit to 30 inches and to recognize a shallow phase for those examples less than 18 inches in depth.

On the Research Station the Chart Series occurs only in six small patches, all of them on the sides of the two dry valleys, where erosion has been more severe. In one place towards the north-western margin of P10 it is so shallow that the ragstone is only four inches below the surface. A group of borings made at intervals of a few yards in the western part of E29, near the implement shed, showed the ragstone to be at 8, 8, 9, 10, 10, and 22 inches respectively. These figures indicate the important fact that the weathered surface of the limestone rock is very uneven. It has dissolved quite deeply in places, while a few inches away solid rock comes very near to the surface.

For this reason fruit trees generally grow better upon the Chart Series than the shallow depth of the rock would lead one to suppose they would. Roots are able to penetrate quite deeply into the soil material which fills the fissures and joints in the ragstone. The fact that fruit tree roots spread over a wide area enables them to seek out and make use of the deeper areas of soil that are almost invariably present in any patch of this series. Nevertheless, the restriction of root run does impose considerable limitation upon the vigour of the trees, which is usually markedly less than on deeper soils.

A further factor which frequently makes itself felt is iron deficiency. Fruit trees are often unable to assimilate adequate supplies of iron in the calcareous soil, with the result that the foliage becomes chlorotic.

Towards the south of P11, near the head of the dry valley, a boring showed soil similar to that of the Chart Series, a calcareous loam 21 inches deep over ragstone, but from 13 inches there were the iron oxide stains characteristic of poor drainage. Almost certainly these are relics of the days when the spring water welled out at this and other points nearby, to flow down the valley across the Park. The springs have subsequently been diverted and the drainage appears to be perfectly free. It has therefore been included with the Chart Series, the soils of which are characteristically well drained.

Wierton Series.

This series (Bane and Jones, 1934) is developed upon hassock. In places where the Hythe Beds are free from drift overlying them, deep seams of hassock, the calcareous sand, have weathered to produce a soil of quite good depth. Yet it is always fairly closely associated with the Chart Series, in places where there has been a good deal of erosion. Five quite small patches were encountered, all of them on the slopes of the dry valleys which cross Kiln and Egham Fields, and the Park.

The soil is generally a medium to heavy loam (silt loam) in texture, although, towards the north-eastern part of P11, some of it contains sufficient drift material in the surface to convert it into a fine sandy loam. The grey-brown surface soil gives place to a medium brown material in which small white calcareous grains from the weathering hassock begin to appear, often as near the surface as 12 inches. Gradually the amounts of calcareous and glauconite grains increase, and the soil becomes steadily more and more ‘ hassocky ’, with a consequent paling of colour. This change is not always even, as layers with more calcareous grains may alternate with darker brown and loamier seams. It is often difficult to ascertain the exact point at which the true soil finishes and the unweathered hassock is reached, but in the present survey soil depths ranged roughly from 18 to 38 inches. Beneath lay the hassock, pale buff to almost white tinged with green, sometimes quite vividly, from the glauconite present. This earthy sand is of friable granular loam texture, containing a good deal of sand. The first seam of ragstone occurred at depths which ranged from 30 inches to more than 62.

The soils of the Wierton Series are well drained and well aerated, and, by virtue of their loamy nature, retain moisture well. Roots penetrate through the soil and are able to draw some of their moisture from the hassock itself. Tree growth is usually quite satisfactory upon the Wierton Series and fruit of good quality is grown upon it. Because the soil is rich in lime throughout, it is not uncommon to find symptoms of iron deficiency in the foliage.

One boring close to the north-east corner of P11 showed brown iron oxide staining and black deposit of manganese dioxide between 12 and 16 inches. These symptoms of poor drainage are probably relics of the time when the stream ran here, before it was diverted.

Medway Series.

Apart from two small patches, the soils of all the Medway Series (Bane and Jones, 1934) on the Station land lie in the shallow dry valley that runs northwards across the Park. It consists partly of alluvial materials from the stream itself and partly of colluvial materials, which have been washed into the valley by erosion and cultivation. Some idea of the recent date of much of this material can be formed from the fact that brick fragments were common to considerable depths, in one case to 62 inches. The lower layers in a number of places contained a good deal of fine gravel, consisting of chert and ragstone fragments, as well as some small flints.

The soil is a fine sandy loam to medium loam which shows little change throughout its depth. The surface is grey-brown in colour, while below the soil becomes a little paler. Grey is usually an important colour throughout, although yellowish shades may appear in combination. Small calcareous grains of hassock are common. Its richness in lime is demonstrated by the presence throughout its profile of small fragments of shells of land snails ; these soon disappear in acid soils but remain in calcareous ones. One soil showed a trace of the mellow texture and warm brown colour of a brick-earth. As it lay close to the patch of Langley Series in P8, it may be concluded that it contained materials washed from that deposit. A relationship between the Medway Series and the Langley Series is not uncommon. Also, from the hassocky nature of some of the soil, an affinity to a deep Wierton Series is also recognizable.

The soils are of good depth, ranging from 36 to more than 62 inches. South of the line of the Sandgate Beds outliers the drainage of these soils is quite free but, once that point is reached, signs of a slight seepage of spring water through the deeper layers appear as a faint clouding or a mottling of the colour of the subsoil. Bane and Jones recognized a poorly-drained phase from this cause, but it would be more in line with the importance now attached to water circulation to regard these as two distinct series. The well-drained soil provides an extensive root run and ample moisture holding capacity, so that tree growth should be vigorous. The soil is incompact and well aerated. Where spring water seeps through, the even greater moisture supply should make for a considerable vegetative growth, especially as it persists throughout the growing season. The fact that it is saturated with lime may well make iron and manganese deficiency matters of no small importance.

Besides the main area of Medway Series in the valley, there are small isolated patches of colluvial origin in P10 and P13, 42 and 38 inches deep over the ragstone respectively.

Malling Series.

The Malling Series (Bane and Jones, 1934) is one of the most widespread on the Research Station. Together with the Barming Series, it makes up by far the largest area. Although they are quite distinct in their typical forms, these two series are closely related ; they fade into one another by way of every possible intermediate form, and are closely interlocked in distribution. Both derive a great deal of their parent material from Pleistocene drift consisting of river sand and fine gravel. In the Malling Series the ragstone and hassock of the Hythe Beds play a big part also, but their influence upon the soils of the Barming Series is less.

In the Malling Series the upper layers are generally of fine sandy loam texture, less frequently very fine sandy loam, and occasionally medium loam. At a depth which varies considerably, but is generally between 18 and 36 inches, the texture stiffens markedly to a sandy clay loam. Then the sand usually decreases and the soil becomes a sticky clay loam. This lies upon the ragstone or hassock. At times, the change from the fine sandy loam upper horizons into clay loam is sharp, without any intervening sandy clay loam.

Beneath the greyish-brown surface soil the colour is the warm brown that is so characteristic of the river drifts. But once the heavier textured horizon is reached, its colour becomes a little darkened by small black stainings of manganese dioxide deposit. Then in most cases there is a layer of ' pug '. The clay loam immediately in contact with the ragstone or hassock is usually dark brown in colour ; or chocolate brown or almost black, if the manganese dioxide is very plentiful. This layer may contain small accumulations of brilliant green grains of glauconite. The pug layer is extremely variable—in one place it may be a foot or so thick, while a few inches away it will shrink to an inch or two, or it may vanish entirely for a short space, soon to re-appear. This dark pug layer is always in contact with the irregular top of the rag and hassock. More usually it follows the highest seam of rag, extending down between the blocks of stone into the fissures. In the less common cases where the pug overlies hassock, darker pug-like seams may traverse the hassock itself, below the main pug layer.

The pug is a layer of accumulation of clay, humus, iron, and manganese, and possesses an extremely sticky texture, with a characteristically greasy feel. It is always plentifully supplied with grains of glauconite. The upper part of the soil, which is light-textured, is a typical acid drift of low base status. In the deeper, heavy-textured material, which contains a considerable contribution from the Hythe Beds and overlies the limestone itself, the reaction changes to alkaline. Here the substances which are mobile in acid solution are deposited to produce the pug horizon.

Although the deeper horizons of the Malling Series contain abundant evidence of the large amount of Hythe Beds material they contain, this appears to have been contributed as a drift, even though of very local derivation. There is little sign of weathering *in situ*, such as is to be seen in the Sutton Series (Bane and Jones, 1934), the sedentary soil produced by the direct weathering of the Hythe Beds. In that series decaying seams of ragstone and hassock can be traced through the lower layers of the soil ; no such vestiges are visible in the Malling Series.

The soils of the Malling Series show a great range of depth. The long dip slope of the Hythe Beds, upon which they lie, has undergone long ages of erosion. This has left its mark upon the drift deposits which cover it. Normally the ragstone or hassock occurs at between 36 and 60 inches, although occasionally deeper examples occur. Shallower ones are much more common, and those in which the rock is encountered between 18 and 36 inches are classed as a shallow phase of the Malling Series.

In a number of places soils were encountered in which the rag or hassock was less than 18 inches below the surface. These might, at first sight, appear to belong to the Chart Series, shallow phase, but they are, in fact, quite distinct. The soils of the Chart Series are dominantly grey in colour and highly calcareous, while these eroded soils are of the warm brown drift colour and are non-calcareous. They are, in fact, eroded examples of the Malling Series. At times the light-textured surface layers are completely absent and the soil is a heavy loam (silt loam) at the surface. In such a case only the deposition horizons of the soil remain. In the present survey these soils are marked separately on the map as the Malling Series, eroded phase, as distinct from the Malling Series, shallow phase.

The Malling Series is a fine agricultural soil. In its typical form it offers a deep root run for crops and possesses a large capacity for holding moisture. It is easy to work, on account of its light surface texture, but its heavier subsoil makes it retentive of plant foods and water. Being acid at the surface and alkaline below, it should present few nutritional problems. Roots abound in the pug layer. The drainage is perfectly free and aeration is good, except when the crumb structure at the surface has broken down. Then the fine grain of the sand particles causes the soil to pan fairly severely.

Tree growth should be vigorous on the Malling Series and all manner of fruit crops should prove satisfactory. The shallow phase is still a good soil and one quite capable of growing sound healthy crops, though no doubt vigour would be rather less. The eroded phase offers a restricted root run, but penetration down the cracks and fissures is some compensation for shallow soil depth. It has the advantage over the Chart Series, shallow phase, of being free from any large amount of lime.

The greater part of Great East Plantation lies upon soil of the Malling Series. So does Kiln Field, except for the valley and the patches of Chart and Wierton Series which border it. The eastern end is on the shallow phase which continues as a strip through Egham Field. The western ends of Newgates and Merryweather Fields also lie on it, as well as a strip on the border of the latter and Deadman Field. Most of Churchfields East lies on the Malling Series, with a fairly large patch of the shallow phase, around which are scattered some smaller ones. A strip runs down the western boundary of Churchfields West spreading into Ditton Fields, P8, and P10. These fields all show other detached areas of the series. There is a fairly large patch in P11, P12, and P13, mainly of the shallow phase.

The eroded phase of the Malling Series is, like the Chart Series, associated only with the dry valleys, where erosion has been greatest. There are three small patches bordering the valley which runs through Kiln and Egham Fields, and two beside the one which runs across the Park. The variability of depth of the ragstone is shown by the fact that borings a few yards apart in Egham Field revealed it at 7, 8, 8, 12, and 20 inches in one patch.

Barming Series.

The Barming Series (Bane and Jones, 1934) is, with the Malling Series, the most extensive on the Research Station. The Barming Series is found where Pleistocene river sands and fine gravel give rise to the soil. These sands and gravel are essentially fine grained and contain relatively few large stones. They vary a great deal from layer to layer in any one spot ; nevertheless, the sand grains are predominantly fine and are mixed with considerable quantities of even finer materials. They fall largely into the sandy loam and loamy fine sand texture groups. Heavier layers are, however, common and many of the borings showed seams of sandy clay loam and, at times, clay loam grades. The amount of fine gravel is very variable from layer to layer, but is generally subordinate to the sandier materials in the soil as a whole.

Some soils of the Barming Series are light throughout, consisting of a deep deposit of fine sandy loam, which becomes interstratified with seams of loamy fine sand beneath, with or without fine gravel consisting of fragments of chert, carstone, and flint, with occasional very fine grained sandstone from the Wealden rocks. Coarse grains of quartzite and lydian are almost always present throughout. Very frequently, however, the deeper layers become heavier, with seams of sandy clay loam and even clay loam. These soils begin to resemble those of the Malling Series. This resemblance is still further heightened by the fact that there is often a dark chocolate brown, greasy-textured layer, rich in manganese dioxide deposit, at the bottom of the soil, in contact with the ragstone or hassock. This pug layer is exactly similar to that of the Malling Series. There is, in fact, no hard and fast boundary between the two series. The criterion applied in separating them has been—whether the influence of the light-textured river sand, or of the heavy-textured material consisting of Hythe Beds debris, was the greater. One result of this has been that, as the deeper the sand and gravel the greater their influence upon the soil, the soils classed in the Barming Series tend, in general, to be deeper than those of the Malling Series. In fact, in a high proportion of the borings it was not possible to reach the ragstone within 62 inches. In a number of places a warm brown mellow loam occurs in the upper layers of the Barming Series, which produces a close relationship with the Langley Series.

Beneath the greyish-brown surface soil the Barming Series exhibits a very even shade of warm brown, of a rather bright hue, tending to be a trifle more orange-brown in colour in the deeper layers than the soils of the Malling Series.

The Barming Series is essentially one of the well-drained soils, as might be expected of a gravelly light loam overlying a fissured limestone, but, where it stretches across the line of small springs which fringe the valley on either side, water seeps through the lower layers. Such a fundamental change in water conditions places the limited patches of soil where this occurs in a separate series, which will be dealt with briefly under the Ditton Series. Besides this, however, the Barming Series stretches beyond the Hythe Beds onto the Sandgate and Folkestone Beds. The influence of the underlying geological material upon a deep river sand soil, such as this, is probably not great, but there are certain effects which should be noted, especially as they may have some influence upon fruit trees grown on it. First, there is no pug layer in the Barming Series once it ceases to overlie the calcareous ragstone and hassock. This may not be a very significant difference where it has the sandy clay loam of the Sandgate Beds beneath it, but on the Folkestone Beds the underlying material is much lighter and less retentive, being a loamy fine sand. There is also evidence of a slight difference in the percolation of surplus water from the lowest layers of the soil. It can run away quite freely through the Hythe Beds, but the river sand overlying the Sandgate Beds shows in places a very faintly clouded colour, which suggests that percolation is a trifle slow. On the Folkestone Beds, on the other hand, the seepage of excess water is not only likely to be very free, but the rock itself is not able to offer a great deal of moisture retaining capacity to augment that of the soil. It should be explained, however, that, as the Barming Series is itself a deep soil, these differences are probably quite slight in their effect upon tree performance.

This does, of course, throw emphasis upon the importance of depth among the characteristics of the Barming Series. For this reason, as in the Malling Series, examples less than 36 inches deep have been differentiated as a shallow phase, even though, as soils in general go, this is in fact still a considerable depth. The nature of the underlying geological material is indicated on the map.

The Barming Series offers a large space for root development. It is incompact, well aerated, and well drained. It has a large capacity for retaining moisture, not only because of its depth but also because it contains a considerable proportion of loamy materials among the fine sand and gravel, as well as heavy seams. It is, therefore, a soil which produces vigorous growth in fruit trees. Like many sand and gravel soils, it is not by nature well supplied with plant foods and nutritional balance needs careful attention.; it can quite easily become very short of organic matter. It is naturally acid in the upper layers but, where it overlies the ragstone, it becomes alkaline in the lowest horizon. It is an easy soil to work and is suitable for most kinds of fruit. Even the shallow phase should give quite satisfactory performance, though not quite so vigorous as the deeper examples. Where it overlies the Sandgate Beds, growth should still be vigorous, but is possibly a trifle less so under the rather drier conditions over the Folkestone Beds. Here the soil is likely to be acid throughout.

A large block of the Barming Series covers a great part of Merryweather and Newgate Fields (the western parts of which consist mainly of the Malling Series) and by far the largest part of Upper Grub and Deadman Field. At the eastern end there is a roughly L-shaped patch where the soil shows iron stainings from 12 to 27 inches, suggestive of poor drainage. This is nearly the highest part of the Research Station and there does not appear to be much likelihood that defective drainage now exists, because the railway runs in a deep cutting bordering the field and severs it from the higher land to the south, from which any seepage of water might have come in the past. The area is marked on the map as belonging to the Ditton Series.

Most of Egham Field west of the dry valley lies on the Barming Series. There is a group of patches of the shallow phase towards the western boundary, in which the depth of soil ranges from 29 to 35 inches over the ragstone.

In Churchfields East the Barming and Malling Series are closely interlocked along the eastern margin and some small shallow patches occur. Separated from this by a central block of Malling Series, Churchfields West, except for the extreme margin, consists of a large block, mainly of Barming Series. The soil here contains a good deal of smooth, mellow-textured, very fine sandy loam in the upper layers, which is strongly reminiscent of brickearth. In places this extends to more than 40 inches deep. The soil here is consequently closely allied to the Langley Series, a patch of which lies upon similar contours a short distance to the west, in P9 and P10.

This stretch of Barming Series extends northwards down the slope into Ditton Fields, most of which it covers. Here again some of the soil shows a similar leaning towards the Langley Series, a considerable patch of which lies just to the westward in P8.

Parallel with this strip and united with it at its northern and southern ends, is a tortuous and narrower stretch of the Barming Series which runs through C7, P10, and P8 into P6 and P7. Towards the northern fringe this begins to run into patches where there is evidence of spring water seeping through the deeper layers. There are patches of the shallow phase in C7 and P10, the latter with soil 18 to 31 inches over the ragstone. This is on the eastern fringe of the dry valley.

On the western brow of the valley there is a narrow strip of the Barming Series and a patch stretches along the roadway separating P11-P13 from P14. The north-western margin of this fades into soil showing evidence of spring water seeping through it. It also shows the influence of the adjoining Langley Series.

On the north side of the main stream there is a long narrow strip of Barming Series lying on the outcrop of the Sandgate Beds. In the western half it ranges from 35 to 44 inches, but in the eastern it is more than 62 inches deep. It stretches from near the middle of P1 to the north of the walled garden, the length of P3, and across P4. In the eastern half of P4 it stretches across the boundary of the Sandgate Beds and on to the Hythe Beds, with ragstone at 54 inches. North-east of the walled garden, at the bottom of P3, and extending into the corner of P5, spring water begins to seep through the sand and gravel of the subsoil and where it stretches over the boundary once more on to the ragstone. There is also a very small patch of Barming Series 36 inches deep over Sandgate Beds in P6, just south-west of Park Farm House, where the long stretch of river sand extends a short way across the boundary of the Hythe Beds onto the Sandgate Beds beyond.

In P2 the Barming Series lies upon the Folkestone Beds. It forms a series of three patches bordering the upper fringes of the broad, shallow valley that extends up the field. There is also a patch towards the centre of the field isolated from the other three by the Langley Series. The depth of river sand soil overlying the Folkestone Beds varies from 40 to more than 62 inches.

Ditton Series.

As stated earlier, at four points on the lower fringes of the larger stretches of the Barming Series, the soil begins to show evidence of spring water seeping through its deeper horizons ; to distinguish such soils, the term Ditton Series is proposed. The soil is composed of the same warm brown river sand, containing fine gravel and also loamy material, as well as becoming heavy in some horizons, as does the Barming Series. The distinction lies, however, in the fact that the colour, instead of being quite even and uniform in each horizon, becomes mottled, consisting of a combination of two or more shades of brown and paler greyish-brown. These may be faintly clouded or more sharply marbled. Besides this there are sometimes rust-coloured stains of iron oxide or small scattered iron oxide concretions, known as crowstone.

As might well be expected, the depth at which these symptoms occur and the intensity of their development vary greatly. The seepage of spring water itself through the subsoil is likely to be very uneven and localized. In any case the areas affected are very small and too much importance should not be attached to them.

In only one patch can the symptoms be regarded as sufficiently severe to be indicative of bad drainage. In the southern corner of P7 there is a small low-lying area where the soil shows quite heavy iron staining from 4 inches below the surface. This badly drained patch extends across the roadway into the south-eastern corner of P6, where the colour of the soil is clouded from 7 inches and iron oxide staining and crowstone are present.

In the southern part of P14, close to its boundary with P13, there is a patch of river sand soil of the Ditton Series, in which there is mottling at 19 to 22 inches—in one place faint clouding was seen at 9 inches—but this does not indicate severe bad drainage. It is rather a continual moistening of the soil by seepage.

Where the Barming Series extends to meet the south-east margin of the Sandgate Beds outlier, towards the north-west corner of P8, there is a patch where there are signs of a slight mottled colour at 40 to 44 inches.

Then to the north-east of the walled garden, athwart the boundary of P3 and P5, half on the Sandgate Beds and half on the ragstone, lies a patch where the colour is mottled at 24 to 30 inches, indicating that water seeps from the hill on which Larkfield Plantation stands into the lower land to the south.

Besides these four areas is the curious one at the eastern end of Upper Grub already referred to when discussing the Barming Series. There mottled colours, iron oxide staining, and crowstone were all found at depths ranging from 9 to 20 inches below the surface.

The only one that seems to be in need of draining is the small, low-lying area in P6 and P7, which lies right on the boundary of the Research Station land. There the bad drainage would be sufficient to cause damage to the roots of fruit crops by cutting off their air supply.

In the other cases it would seem that the generous supply of moisture afforded by the spring water throughout the growing season would make for vigour of growth, which might, of course, be excessive for some sorts of fruit, such as dessert apples. It is possible that the fact that the water would be saturated with lime might lead to nutritional difficulties, but this would to a certain extent be mitigated by the freely draining, light-textured top soil which is naturally low in bases.

Langley Series.

The Langley Series (Bane and Jones, 1934) is the brickearth soil of the Lower Greensand area. It consists essentially of a deep, mellow-textured, medium loam or very fine sandy loam. Like all brickearth soils, it has a characteristically smooth and silky texture. Beneath the greyish-brown surface soil the colour is a warm brown, which also is typical of brickearth. The Langley Series is freely drained ; the few examples where spring water seeps through the subsoil belong to the Brices Series, which is described below.

Sometimes the soil stiffens somewhat in the lower part, passing into a heavy loam (silt loam). In such cases, where the brickearth lies directly upon rag or hassock, a stickier, dark brown layer is often present, corresponding to the pug in the Malling and Barming Series. This contains a good deal of manganese dioxide deposit. In many cases, however, the reverse is the case and the brickearth becomes coarser grained, lighter textured beneath, and frequently contains fine gravel. The brickearth material does, in fact, fade into loamy fine sand and gravel of exactly similar nature to that of which the Barming Series is composed. There are thus two somewhat different developments of this series. Both were found closely associated together but, as a whole, in the Langley Series east of the Laboratories medium loam passing into heavy loam below is the predominant type, whereas to the west it is largely a very fine sandy loam, lying upon a loamy fine sand and gravel. In this western part the Langley Series and the Barming Series are very closely associated with one another. It has already been noted that the soils of the Barming Series in this area show seams of brickearth material in their upper layers. There is, in fact, no absolutely hard and fast line between the two series in this area. It is, once again, a matter of drawing an arbitrary line between them, according to whether the brickearth or the underlying river sand and gravel has the dominant influence in these intermediate soils.

The surface soil often has a considerably coarser sand particle size than one would associate with a brickearth. This is due to surface creep, which has brought materials from the adjacent Barming Series onto the Langley Series.

The Langley Series lies not only upon the Hythe Beds but there is a fairly large patch north-west of Bradbourne House, which stretches across the junction of the Sandgate Beds and Folkestone Beds, covering both. In a part of this the Sandgate Beds hold up the drainage and convert the soil into the Brices Series.

As in the case of the other soils of the deep drifts, examples less than 36 inches in depth have been differentiated as shallow phases. Where this occurs, the rock beneath is likely to exert more influence upon crop growth than in the deeper examples. Thus, where Hythe Beds, Sandgate Beds, or Folkestone Beds occur nearer to the surface than 36 inches, their presence is indicated upon the map.

The county of Kent is famous for its brickearth soils. It has long been the tradition to plant cherries upon them and the Langley Series has often been selected for that purpose. It is a first class soil for all manner of fruits and, providing as it does an excellent environment for roots, the vigour of growth of most varieties is considerable. The soil is deep, so it provides accommodation for an extensive root system and, being fine grained, it has a large capacity for retaining moisture. Drainage is quite free and aeration is good ; this is partly due to the fact that the soil develops a pronounced structure in its deeper layers. It tends to cleave into prismatic columns, between which air and water pass freely. The soil itself has a very porous nature due to the plentiful small channels left by the decay of rootlets. The brickearth soils are often naturally deficient in plant foods, particularly potash, so in spite of their excellent physical characteristics, growth can be unsatisfactory if the nutrition is at fault.

The shallow phases, offering as they do a good depth of mellow loam, are still considerably deeper than many soils of the district. They are good fruit soils and should produce good growth. Those on the Folkestone Beds are likely to be somewhat drier than those on the Hythe Beds and Sandgate Beds, so may give rather less vigour. They may possibly reach a higher degree of acidity than those on the Hythe Beds.

There are three fairly-well defined areas where the Langley Series occurs on the Research Station. First, it occurs in a strip which runs right across Kiln Field and Egham Field, occupying the floor of the dry valley. Almost throughout, this is of medium loam texture stiffening to heavy loam in the lowest part and passing fairly sharply to rag or hassock. Only in a few cases was a sandy and gravelly layer encountered beneath the true brickearth. Several borings showed a pug layer. Small isolated patches of the Langley Series occur in K2, N1, N4, and E23. Secondly, on the long, gentle northward slope of the ragstone which stretches from the Church to the lake, there are five patches of brickearth, four of which give rise to the Langley Series. These contain rather more very fine sand than the brickearths of the eastern part of the Station and they fade into sandier and more gravelly materials in their lower layers. They also fade gradually at their margins into soils of the Barming Series. Pug was encountered in several places. These patches occur in P6, P8, P9 and P10, and P12 and P14.

North of the stream there is a quite large area stretching from P1, right up to P2, to the London Road and to the boundary of Larkfield Plantation. Here also the Langley Series contains a good deal of very fine sand throughout and passes into a coarser and sandier drift beneath. In the southern part it overlies the Sandgate Beds, and in the northern the Folkestone Beds, there being a patch of the shallow phase on each, the depth of brickearth being 23 to 33 and 35 inches respectively.

There is also a small strip of Langley Series in the little valley that runs southwards from the middle of Larkfield Plantation. Here the brickearth is buried under 33 to 39 inches of downwash from the Folkestone Beds. Thus the soil begins to be transitional with the Lowlands Series, but the depth and retentive power of the brickearth weighs in favour of its inclusion in the Langley Series. In the north-east corner of P4, right on the boundary of the Station's land, there is another patch of brickearth similarly buried under 39 inches of fine sandy loam downwash.

Brices Series.

The Brices Series (Brade-Birks and Furneaux, 1930) comprises the brickearth soils which show evidence of the seepage of small quantities of water through their deeper layers. The brickearth is itself freely pervious but, either because of its low-lying position, or because of the fact that it lies upon less permeable material, water from higher land seeps through the subsoil. The upper layers are well drained and exhibit the same warm brown colour as the soils of the Langley Series but, at depths ranging from 24 to 46 inches, this becomes clouded with pale grey shades and, in some cases, quite heavily mottled with brown, pale brown, yellow, and orange. Besides these colorations most cases showed some of the small concretions of iron oxide, known as crowstone. In some cases these symptoms vanish from the lowest layers of the soil, which resume the even, warm brown colour of the upper layers. All these brickearths are of very fine sandy loam texture.

Three small patches of the Brices Series occur on the Station. There is a narrow strip at the lower margin of the patch of brickearth in P14. Here the brickearth is more than 62 inches deep, and signs of poor drainage occur at 24 inches. A second patch skirts the lower slope on the north-west side of the outlier of Sandgate Beds at the south-east angle of the lake. Here 24 to 26 inches of rather sticky, very fine sandy loam downwash from the Sandgate Beds slope covers the brickearth. It is more than 62 inches deep, with symptoms of poor drainage from 24 to 46 inches below the surface. The third patch lies on both sides of the drive at the Mount Memorial gateway. Forty-three inches of brickearth cover the Sandgate Beds, and signs of poor drainage begin at 27 inches.

In the Brices Series there is an adequate depth of well drained soil for most fruit crops to develop a good root system, while the seepage offers a plentiful moisture supply. Cherries, however, would be unlikely to do well on this soil, and dessert apples would be liable to rank growth and canker. Dessert gooseberries would also be risky on this series. Apart from these crops, most sorts of fruit should succeed and grow with good vigour. The fact that the ground water is saturated with lime might lead to iron and manganese deficiency, although this is not likely to be severe.

Soils of the Sandgate Beds area.

Besides soils of the Barming and Langley Series which stretch across the outcrop of the Sandgate Beds, as described above, there are soils derived directly from the Sandgate Beds themselves.

Roseacre Series.

The Roseacre Series (Bane and Jones, 1934) is derived from the Sandgate Beds by direct weathering. On the Research Station this geological formation is fairly constant in its character, being a clay containing a considerable proportion of fine sand. Much of this consists of glauconite, which imparts a distinctly green shade to the rock throughout the entire area. In other places the Sandgate Beds contain strata of clay, seams of sand, and at times beds of fuller's earth, as well as occasional layers of limestone closely resembling the ragstone of the Hythe Beds. On the Research Station, however, only one boring showed clay and the few seams of sand were thin and unimportant. They are, on the whole, very uniform and consist lithologically of the fine sandy clay which is the material most typical of the Sandgate Beds.

Some way below the surface the Sandgate Beds are an even greenish-brown colour which can best be described as khaki ; sometimes ochreous seams of orange-brown colour occur. Nearer to the surface, where they are more subject to the effects of weathering, the greenish shades become brighter and more pronounced and orange-brown flecking becomes plentiful, often developing into a bright mottle. This is a purely geological phenomenon and is quite distinct from the mottled colours which are so often produced in soils where the drainage is deficient. In a number of cases they persist into the lower part of the soil itself, growing gradually fainter. It is, in fact, generally very difficult in the case of the soils of the Roseacre Series to define exact depths at which the soil ends and the rock begins. The lowest layer of the soil fades very gradually into the rock, which itself shows slight signs of weathering for some distance.

Nevertheless, slight variations in depth of soil are recognizable. This is due partly to the effects of erosion and partly to the fact that there appears to be a small amount of drift material mixed in the surface layers in a few examples. Thus it would seem that the depth of the average soil is some 22 to 34 inches, while on the top of the hillock to the south of the lake, erosion has washed away a little of the top soil, reducing it to 16 to 20 inches. Considering the ease with which fine sand grains are washed, the effect is very slight.

The soils of the Roseacre Series are comparatively freely drained, though percolation is slower than that of most of those of other series on the Research Station land, owing to the heavier texture of the Sandgate Beds beneath. In the few cases encountered, where there were definite signs of poor drainage, the soil has been distinguished as belonging to the Stone Hill Series, in which Lee (1931) allowed a greater latitude of defective drainage than did Bane and Jones (1934), for the Roseacre Series. No soils were seen of sufficiently bad drainage to be classed as belonging to the Calehill Series.

The surface layer of the Roseacre Series is a fine sandy loam, or sometimes very fine sandy loam, which possesses a peculiar stickiness when wet. This stickiness is characteristic of soils formed from rocks containing a high proportion of glauconite. Unless they are kept well supplied with organic matter these soils will dry very ' steely ', especially if they are cultivated when they are too wet. Beneath, the soil stiffens gradually to a fine sandy clay loam, while the geological material is usually of similar texture, although it may sometimes become a fine sandy clay.

The surface soil is a grey-brown colour, generally a little greyer and darker than that of the Malling and Barming Series which cover so much of the land nearby. It is usually some 9 to 10 inches deep, shallowing to 7 or 8 where there has been slight erosion, and deepening to 12 towards the foot of the slopes. It passes into a yellowish-brown soil below, which is frequently quite obviously tinged with green. This shows only a very faint brightening of the colour with depth and may be accompanied by a gentle clouding with orange-brown and greenish shades. The transition into the greenish-brown Sandgate Beds beneath, flecked with orange, is very gradual and devoid of any sharp horizonation.

The soils of the Roseacre Series are of medium quality for fruitgrowing and are better suited to the more robust kinds than to the fastidious ones, largely because of the less free percolation of water. Cherries would dislike this, as well as the heavy texture of the deeper layers. The soil is, however, of sound medium depth and would provide perfectly adequate root run for those crops, such as the majority of culinary apples, plums, and pears, which can tolerate somewhat wet conditions of relatively short duration. For soft fruit cultivation the peculiar stickiness in a soil so sandy calls for skill in handling.

The Roseacre Series occurs in three places on the Research Station. The main outcrop of the Sandgate Beds is largely buried under drift deposits, and appears at the surface in only one small area at the western boundary. It gives rise to the Roseacre Series in the central and south-western part of P1, although here the soil begins to be a little lighter-textured than usual as it nears its junction with the overlying Folkestone Beds, and percolation becomes rather freer. The other two areas are found upon the Sandgate Beds outliers. One of these is also at the western boundary of the Research Station but farther south, in the northern part of P13 ; it consists of a small patch developed on stiff Sandgate Beds, through which runs a seven-inch seam of buff-coloured sand. The second—the main block of this series—occupies the other outlier, which lies to the south-east and east of the lake, where it covers a quite considerable area. It rises as a gentle ridge which runs from the middle of the eastern boundary of P14 and P8, stretching north-eastwards through Park Farm and beyond. It extends over most of P16, all except the northern strip of P17, and the higher, western margin of P6. The land falls gently from the crest of the ridge in every direction and it is 21 feet above the stream immediately to the north ; it falls about 6 feet to the southward, too. This has led to a certain amount of erosion, though the depth of soil at the brow is still 16 inches, which compares with 24 to 27 inches where the slope is gentler to the north-east.

Stone Hill Series.

In three small patches the drainage of the soil formed from the Sandgate Beds falls below the requirements for the Roseacre Series. The subsoil shows mottled colorations which indicate that poor drainage conditions persist for longer periods, but, nevertheless, it is not subject to the waterlogging found in the Calehill Series. These soils fall within the Stone Hill Series of Lee (1931), although it seems probable that when he created the series he had in mind to include the better drained soils described under the heading of the Roseacre Series as well. It is undoubtedly wiser to separate the two to avoid including too great a latitude of drainage conditions in the one series. The name Stone Hill Series has therefore been applied only to the sedentary soils of poor drainage developed upon the Sandgate Beds.

These soils are distinguished from those of the Roseacre Series only by the quite bright bad-drainage mottling to be found in the subsoil, while the bright colours in the upper part of the Sandgate Beds themselves are almost certainly somewhat heightened from the same cause.

The soils were 27 to 28 inches deep, except at the northern margin of P17, where they have been increased to 34 inches by materials washed down the gentle northern slope of the Sandgate Beds ridge. The surface soil is a fine sandy loam stiffening below to a fine sandy clay loam, except in the case of the small patch in the north-west corner of P13. There the fine sand disappears and the texture becomes silty clay loam, while the Sandgate Beds beneath contain the only really heavy stratum encountered in them on the Research Station. They are a silty clay in texture and represent the very base of the formation, as the ragstone of the Hythe Beds below was struck at a depth of 53 inches.

The surface soil is grey-brown, but it passes into a yellowish-brown beneath, in which bright orange-brown and greenish-grey mottlings appear at 13 to 17 inches—at 24 inches in the deeper examples. This is the level to which poor drainage extends during wet periods. Below the soil, the Sandgate Beds themselves are brightly marbled with shades of green, orange, yellow, brown, and grey.

Although these soils cannot be said to be subject to actual waterlogging, prolonged periods of wet weather would produce in them conditions which would be likely to cause damage and asphyxiation of the roots of many fruit crops. If they were pipe drained, however, and managed in such a way as to maintain a good structure in the soil, they could be brought to approximate in performance to the soils of the Roseacre Series.

Besides the two patches referred to above, in the north-west corner of P13 and at the lower northern margin of P17, there is a very small area in the north-east corner of P14, on the gentle slope of the Sandgate Beds outlier, just north-east of the crest of the ridge.

Highworth Series.

Just to the north-east of the highest part of the Sandgate Beds ridge there is an elongated strip where a chert gravel with some flint is mixed in with the soil, making it very stony in the upper horizons. This is the last vestige of a cap of drift which must at one time have been much more extensive. Now the chert fragments which originate from the Hythe Beds, as well as some coarse sand, are mixed with Sandgate Beds materials in a soil 42 inches deep. Beneath this is the typical green-tinged yellowish-brown sandy clay loam of the Sandgate Beds. This appears to be a gravelly phase of the Highworth Series of Lee (1931), although his original description is somewhat inadequate.

The surface soil is a greyish-brown fine sandy loam some 9 inches deep, containing numerous chert fragments. Below this the soil is a greenish-tinted medium brown of similar texture and little less stony. At 24 inches the colour becomes orange-brown and the soil stiffens to fine sandy clay loam in which there are still quantities of chert, fine flint, and some coarse sand. At 42 inches are the greenish-yellow-brown Sandgate Beds, rich in glauconite. The drainage appears to be quite good.

It occupies a small area only, about 400 feet long and 150 feet wide, at the western border of P6, close to the hilltop. It is a soil series of local distribution only, occurring close to the junction of the Sandgate and Hythe Beds where materials from both have become mixed together, but with the former predominating. As a fruit soil it is likely to differ little from a deep example of the Roseacre Series, although the stony surface may well lead to greater difficulty in some cultivations.

Sevington Series.

At the upper boundary of the outcrop of the Sandgate Beds, where the Folkestone Beds overlie them, some of the sand is found washed down from the latter formation on to the stiffer Sandgate Beds. Strips of soil are thus formed in which the upper layers are light and sandy but the deeper parts are clay loams, though containing a good deal of fine sand. These belong to the Sevington Series described by both Lee (1931), and Bane and Jones (1934). As might be expected, soils of this series are quite widely distributed, but only in small patches. The Research Station is no exception, for the strip of the Sevington Series which runs along the upper part of P3 and P4 and into the south-west corner of L8, is very narrow and at one point it is interrupted by the Barming Series. At both extremities the surface soil contains a good deal of flints which have been washed on to it from the thin gravel deposit that lies upon the hilltop. At the eastern end the upper part of the soil consists almost entirely of downwash from the Folkestone Beds, while in the patch at the western end there is an admixture of river drift, bringing it into close relationship with the Barming Series, into which it projects as a salient.

Here the soil is rather loamier than in the eastern part and is of a warmer brown colour, consisting of 31 inches of fine sandy loam over the dull orange-brown sandy clay loam of the Sandgate Beds, streaked with green and red-brown, and rich in the green grains of glauconite. Eastwards the downwash becomes lighter in texture, being a loamy fine sand, and assumes the greyer-brown colours characteristic of the Folkestone Beds colluvia. The depth gradually increases from 33 to 45 inches before the Sandgate Beds are reached. The drainage is quite free throughout.

The Sevington Series offers an ample depth for rooting and its light incompact surface layers allow of good aeration, while the more retentive subsoil provided by the Sandgate Beds conserves moisture and plant foods. It is, therefore, a group of soils that has given quite satisfactory performance with most kinds of fruit.

Soils of the Folkestone Beds area.

Bearsted Series.

The Bearsted Series (Bane and Jones, 1934) is produced by the direct weathering of the yellowish-brown sands of the Folkestone Beds to form a sedentary soil. As is so often the case, however, the low hills formed by them are capped by a shallow deposit of gravel, composed mainly of flints but with a little chert. Among the finer materials of the soil, there is little that is from elsewhere than the Folkestone Beds, but the gravel is evidence of a resorting of the surface materials, which leads to the production of soils mainly somewhat deeper than those described by Jones. The range of depth was here found to be from 20 to 38 inches, while the soils of 18 inches and shallower are distinguished as a shallow phase. At the same time, the soils, where the flints are sufficiently plentiful to justify it, have been mapped as a gravelly phase. Even throughout much of the remainder they are fairly numerous.

The surface soil is a grey-brown loamy fine sand, in places reaching fine sandy loam, the amount of gravel varying greatly. This passes into a yellow-brown to medium brown material, generally a trifle lighter in texture. It is usually a loamy sand or loamy fine sand, but in many cases the size of sand grains is considerably mixed, so that, in spite of the fact that the general texture may be loamy fine sand, there may be a quite appreciable quantity of coarse grains as well. Beneath lie the Folkestone Beds, generally greenish-tinted, yellow-brown, and often showing a similar diversity of particle size. The dominance of one size or another may vary from stratum to stratum.

The drainage is very free and moisture retention is poor. Towards the southern margin of the Folkestone Beds outcrop, where they overlie the Sandgate Beds, there is a tendency for the sand to be fine, for glauconite to increase, and for the material to become a little stickier. The soil is likely to be somewhat more retentive of moisture in consequence.

In two patches the sand grains in the surface horizon sparkle brightly, being free from any iron deposit. This is almost certainly the result of the soil having previously been podsolized. In fact, in one boring the grey-brown colour of the soil was tinged with purple, a shade which is often present in the podsols of the Folkestone Beds. There are numerous places in the near vicinity where highly podsolized soils of the Hothfield Series (Lee, 1931 ; Bane and Jones, 1934) have been developed under a vegetation of pine trees and heather (*Pinus sylvestris* and *Calluna vulgaris*). In all probability the soils showing these bright sand grains were reclaimed years ago from heathland and brought under cultivation.

Fruit trees on the Bearsted Series usually grow slowly and require to be carefully managed, because they suffer from moisture shortage. They are very susceptible to the effects of drought and grow best in rainy seasons, while they take no harm from the wettest of spells. Irrigation is widely practised on this series for market garden crops. The fact that the soil is light, and that much of the land in the past has been very acid, and some of it probably reclaimed from podsol, presents the possibility of nutritional deficiencies. Nevertheless, good dessert apples can be grown on these soils.

On the Research Station the Folkestone Beds outcrop along the northern boundary of the estate. They reach the surface to give rise to the soil in two areas, separated from one another by the stretch of drifts which bury them under Langley and Barming Series in P2. In spite of this they appear in the western corner of P2, a little north of the Mount Memorial Gateway. Here the soil is 24 to 34 inches deep and shows the bright sand grains that suggest that it was formerly podsolized.

The main block of the Bearsted Series lies almost entirely within Larkfield Plantation, although it stretches a short way beyond into P3, giving rise to a very narrow strip at the top of that field. This block is itself cut into two by the slight valley which runs up L5 and swings off to the north-east corner of L7. In the southern part this valley contains a narrow strip of brickearth of the Langley Series. As it widens and shallows north-eastwards, it is filled with a downwash from the Folkestone Beds, giving rise to the Lowlands Series described below. On both sides of this break the southern part of the Bearsted Series is relatively free from flints, but, where the land rises to a gentle summit to east and west, the stony drift material produces a gravelly phase. At the western margin of L1 and in the south-eastern corner of L7, erosion has produced a shallow phase, which affects both the ordinary Bearsted soil and the gravelly phase in each case ; the western patch contains soil 18 inches deep over light sandy Folkestone Beds. This is a narrow strip which passes northwards into the projecting portion of P2. Here there is a depression in the ground which must formerly have been a small sand-pit, long since abandoned ; on the lip of this, the soil shallows to only 12 inches. In the patch at the south-east corner of L7 the depth of soil is 18 inches, belonging to the gravelly phase at the northern end. Southwards, the stones grow less and so does the soil, which decreases to 15 inches, becoming loamier and stickier as it comes close to the junction of the Folkestone Beds with the Sandgate Beds lying beneath them.

Lowlands Series.

The Lowlands Series, as described by Bane and Jones (1934), consists of a deep accumulation in the valleys and on the lower slopes from the long-continued washing of soil from the hillocks of the Folkestone Beds. The soils are generally very uniform greyish-brown fine sandy loams, or loamy fine sands, of free drainage.

The soils of the Research Station which have been placed in the Lowlands Series do not fall exactly within the strictest limits of this definition, but they are sufficiently close for there to be little difference in practice. On the Research Station the Folkestone Beds in these slight valleys are covered by a thin layer of sandy drift containing a little fine flint gravel. This is material of alluvial origin similar to that from which the Barming Series is formed. Soil from the higher land of the Folkestone Beds has been washed on top of this and has buried it. Thus, instead of the whole soil consisting of downwash, only the upper 33 to 39 inches are so formed. Beneath this the drift material is of similar texture, but of warmer brown colour than the greyish-brown of the colluvial soil, and also containing rather more small flints. On the Research Station land even the true downwash materials of the upper layers of the Lowlands Series contain flints, because of the gravel caps on the Folkestone Beds. Thus nearly all the Lowlands Series belongs to the gravelly phase. In one strip running across L4, L5, and L6, the amount of gravel becomes so much that the soil approaches quite closely to that of the Willesborough Series (Lee, 1931 ; Bane and Jones, 1934), which is a true river gravel.

There is one small patch where the soil is typical of the Lowlands Series. This lies in P2, between the north-western corner of L1 and the houses on the main London-Maidstone road. Here there is more than 62 inches of a greyish-brown fine sandy loam, possessing a slight yellowish tinge in the deeper layers. This soil is wholly of colluvial origin.

The Lowlands Series is quite a good soil for fruitgrowing. Its depth allows the formation of a large root system and compensates for the relatively low retentive power of its light-textured materials. Aeration is good and drainage very free. It is, however, naturally deficient in plant foods.

The main block of this series lies in the centre and north-eastern part of Larkfield Plantation, where the land begins to slope very gently north-eastwards, away from the valley of the Bradbourne stream. All of this belongs to the gravelly phase, although the amount of gravel, as well as the texture of the various horizons in the soil itself, is very inconstant. The most gravelly strip, which closely resembles the Willesborough Series, stretches from the middle of the eastern side of L4 north-eastwards across the northern part of L7. Throughout the remainder the drift materials which the soil contains, cause it to approach the Barming Series to some extent.

There are four small detached areas in P2, one of which slightly encroaches on to the north-west corner of L1. A second lies to the north of L1 and is in a small hollow, in the bottom of which forty inches of downwash have collected over the Folkestone Beds ; this is a shallow phase of the Lowlands Series. A third lies at the south-eastern corner of P2 in a very slight valley in which more than 62 inches of fine sandy loam has collected. This is largely material from the Folkestone Beds but contains a little drift mixed with it, which gives it a slightly browner hue than is typical, while it contains some small flints throughout. The fact that it actually lies on the Sandgate Beds gives it better retentive power, but the downwash is too deep for it to be placed in the Sevington Series. The fourth patch lies close to the north-western boundary. It is shallow in that the soil is only 38 inches over the Folkestone Beds, and it resembles the main block in Larkfield Plantation in the fact that the lowest 12 inches of the soil is river drift ; it is not gravelly, however.

Soils of the Alluvial area in the valleys.

In examining the distribution of these soils, it is important to remember that the streams have occupied their present courses for only a relatively short time. They have been canalized and a lake constructed, the water of which stands well above the adjacent land in B5. Thus, alluvial deposits quite recently laid down by them lie at some distance from the present brooks.

They consist of gravels, largely composed of flints, ragstone, and chert, sands of varying particle sizes, and layers of silt. The nature of the material deposited in any spot has been determined largely by the speed of flow of the water. Where it has run swiftly only gravel could rest, but possibly only a few feet away, where there was quieter water, silt may have accumulated. Hence, in most of the borings quite considerable changes in texture were encountered at different depths, and examples quite close together often showed a quite dissimilar arrangement of layers. Thus, for practical purposes it becomes quite impossible to single out any profile as being typical of a particular area.

Nevertheless, one important distinction emerges among these alluvial soils : some are highly calcareous, while others are not. This is an important difference when one bears in mind the fact that almost all of them possess a permanent water table within easy reach of the roots of crops. In the presence of large quantities of free lime, such conditions lead to nutritional problems, particularly deficiencies of iron and manganese. Some of the fruit trees already show clear evidence of this.

The water that emerges from the springs is largely saturated with lime and a great deal of the silt, of which many of these soils are composed, consists of calcium carbonate precipitated from solution.

Three series of alluvial soils have been distinguished in the valleys and are described below.

Bradbourne Series.

These soils, for which the name Bradbourne Series is proposed, lie mainly in a strip which stretches the whole width of Bradbourne bordering the stream, but there are also two small detached areas. They are calcareous stream gravels, sands, and silts, with a permanent water table. The one covering the north-west corner of P13 and the south-west corner of P14 resembles the main block, but the other requires special notice. It forms a long narrow strip on the eastern margin of P11, lying on the eastern slope of the slight valley, the floor of which is occupied by a similar elongated strip of the Medway Series.

Here there is from 41 to more than 62 inches of alluvial deposit over the ragstone, except in one place near the eastern end, where the rock was encountered at 28 inches. The soil is a loam at the surface, becoming sandier and gravelly beneath, but at the same time stiffening in most borings to sandy clay loam, only to lighten once more to medium loam lower down. The soil is highly calcareous and contains numerous small fragments of ragstone, as well as a quantity of small concretions of calcium carbonate. In one place there is a seam of lemon yellow sand. At depths which range from 12 to 29 inches, there is quite heavy yellow-brown iron oxide staining ; deeper down this becomes dark brown, while heavy deposits of black manganese dioxide occur. These are typical of the symptoms of bad drainage and must have been caused by the issue of spring water out of the ragstone. There is every indication that this represents a state of affairs which has now ceased. In spite of the iron staining, this soil and those which surround it seem to be quite well drained. The symptoms are, in fact, probably relics of the days when the brook, which now runs beside the road to the west of the Park, flowed down this small valley instead.

The other detached area of the Bradbourne Series is, nevertheless, connected with the main mass by a large stretch of non-calcareous alluvium in P14. It is separated by the road only from the brook that runs close by and it appears that there is a fair seepage of water through the subsoil. At the southernmost corner, the Sandgate Beds lie 44 inches beneath the surface, but most of it is over ragstone at 39 to 43 inches.

In the main stretch of this series, the surface soil varies from fine sandy loam to medium loam and is a fairly dark grey-brown when moist, but it becomes very pale when dry. For a depth which varies from 21 to 38 inches the material remains mainly fine grained, while grey is the predominating colour. At times this may be quite a pale grey, often clouded with deeper shades, but in a number of cases the deeper layers assume a very dark slate-grey. This material is highly calcareous and small calcium carbonate concretions are often present, while minute fragments of the shells of snails lie undissolved in the soil.

Beneath this the soil becomes sandier, ranging from fine sandy loam to loamy fine sand, while it may or may not become gravelly at the same time. The colour, too, changes by the appearance of yellow shades, becoming yellowish-grey or yellowish-brown, or even orange coloured. With depth, fragments of flint and chert and small quartzite pebbles become more common, often producing seams of sheer gravel. This is sometimes quite heavily stained with rusty iron oxide colours.

The colours in the soil are, however, no reliable indication of the height of the water table. The clouded, grey colours and the faint, yellow stains in highly calcareous soils are often difficult to interpret but, when the water levels have been greatly altered by the construction of an artificial lake and the diversion of streams, they can become misleading. Equally, the speed with which water flows into a boring can differ greatly according to the nature of the seams it penetrates. Some gravel layers may carry water freely, while compact seams of very fine sandy loam may do quite the reverse. Suffice it to say that the soil is freely draining at the surface and for a depth of some 18 to 48 inches, but that a plentiful supply of water is available from underground sources and that this is saturated with lime. In many cases the alluvial material was found to be more than 62 inches deep, but ragstone and hassock were encountered in places at depths from 30 inches downward. As the limestone is much fissured, water can, of course, pass freely through it into the soil, as well as in the reverse direction.

In most places this soil is deep and possesses a pleasant texture, but the excessive quantity of lime it contains is likely to cause nutritional difficulties with many fruit crops, especially where the water table is high. All crops would benefit from the maintenance of as low a water table as possible, so as to reduce as far as practicable their dependence upon the lime-saturated ground water.

Apart from the isolated areas already described, these soils form the south-western border of the lake in P14 and most of its northern margin, as well as lining the northern bank of the stream that flows from it. It gives rise to much of the lawns, B5, and B6, while a strip runs up through the walled garden (B1), across P5 to the south-east corner of P3, and tapers out in P4, just reaching the outcrop of the Sandgate Beds, at a depth of 37 inches.

Millhall Series.

In two areas the development of white calcareous concretions in the alluvial deposit is more marked than in the Bradbourne Series, while the general contribution of lime precipitated from solution tends to be greater and the influence of sand and gravel smaller, at least in the upper part of the soil. It is closely related to the preceding series but the plentiful occurrence of the concretions, which in a number of places reach half an inch in diameter, seemed sufficient justification for mapping it separately under the title of the Millhall Series. In places the concretions are so numerous as to constitute a bed of coarse sand. The larger concretions show concentric rings of growth.

The soil itself is a very fine sandy loam, dark brownish-grey at the surface, but becoming pale grey beneath. Clouded colorations suggest that the water table reaches 22 to 24 inches on occasions. In some places the alluvium was more than 62 inches deep, but in others ragstone or hassock were encountered at depths which ranged from 30 inches downwards. In the southern part of P4 the Sandgate Beds were found at 43 inches, with the ragstone beneath them at 59 inches. In the northern part of B5 the calcareous concretionary deposit lay on gravel at 33 to 43 inches.

From the point of view of fruitgrowing there seems to be little difference between the soils of the Millhall and the Bradbourne Series.

On the Research Station the Millhall Series occurs in two patches, both surrounded by the Bradbourne Series. The one is a small patch in the south-western part of B6, while the other is a long strip extending from the northern part of B5, diagonally across the middle of P5, from south-west to north-east, and across the lower part of P4 where it terminates.

Twisden Series.

Some of the stream deposits, when tested with dilute hydrochloric acid, showed remarkably less calcium carbonate than those already described, and no sign of effervescence could be detected until the last few inches above the ragstone were reached. They were mainly dark grey-brown, very fine sandy loams at the surface, but deeper down they became pale buff or yellow-brown. This colour was clouded or slightly mottled, owing to the presence of water seeping through the deeper layers. The depth at which the mottling made its appearance ranged from 14 to 36 inches. The deeper soil tended generally to become sandier in texture, passing into a loamy sand or loamy fine sand, generally mixed with a good deal of fine flint and chert gravel, with small quartzite pebbles. Sometimes, however, it stiffened to silt loam, though always mixed with some coarse sand and fine gravel.

This material was altogether much more uniform in character than the calcareous alluvia of the Bradbourne and Millhall Series, and is here distinguished as the Twisden Series. In only one case was the ragstone deeper than 62 inches, the others ranging from 39 inches. West of Bradbourne House this drift extends beyond the ragstone onto the Sandgate Beds for a short distance. That formation was encountered at 43 to 44 inches.

It is a deep soil with a plentiful water supply, which should prove a very satisfactory one for those fruit crops that appreciate ample moisture—such as pears, black currants, and strawberries. It appears to be free from the threat of excess of lime which detracts from some of the land nearby.

It occurs in one main block and two smaller patches. The first comprises a compact area in the western half of P14. It extends eastwards from the road a little more than half way to the eastern boundary, but does not include the northern or southern margins of the field. The second area forms a strip from the eastern corner of P1 and the northern part of B6, through the western half of B2; the western end of this strip overlies the Sandgate Beds. There is a third small patch which lies towards the western end of P5 and extends a little way northwards into P3.

Made land.

There are upon the Research Station several areas of 'made land'; these are indicated on the map.

By far the most important is B7, the 'delta' in the lake, which was built entirely from the silt dredged out when the lake was cleaned and restored in 1948. This is composed very largely of calcium carbonate precipitated from solution in the water. It is remarkably uniform in particle size and is of silt loam texture throughout. The colour is grey, and varies from pale to dark according to the amount of organic matter present, while some seams are tinged with yellow or brown. The surface layer, like most highly calcareous soils, is almost white when dry, but dark grey when wet. The 'delta' possesses a permanent water table, the depth of which is graduated by the land having been made into a series of broad shallow steps rising above the water level of the lake. Pipes were laid through the island below the water, from one side to the other, to enable it to soak freely into the ground. However, this it appears to do very unevenly, because the soil has tended to pack down very closely owing to the very uniformly fine particle size. The area is similar to some of the calcareous alluvial soils and similar performance in fruit trees can be expected. The outstanding feature is the liability to iron and manganese deficiency, resulting from the very high content of lime and the proximity to the surface of the water table.

In the immediate vicinity of Bradbourne House and the Stable Block, there are various patches of 'made land', as there nearly always are near ancient habitations; the round island in the lake is artificial, as are the raised banks of the lake towards its north-eastern extremity.

Several small areas have been built up by the dumping of excavated soil in the period 1951-1953. These include two areas in P14, the largest being just east of the Sports Field; one in P10 near the junction of the field roads, and one comprising the site of the old ponds lying north of the Church and the land to the south of the road as far as the lodge garden.

There is, in addition, the triangular area to the south-west of Newgates Field, often called Dan's Land, which comprises the site of an old quarry since filled in with many feet of material.

DISCUSSION

With seventeen series making their appearance upon its land, and some of these exhibiting several different phases, the Research Station possesses a wealth of soil variety. There is nothing unusual in this, however, as the soil pattern throughout most of south-east England is one of considerable complexity. It offers the opportunity of giving each kind of fruit the conditions which will suit it, or of testing any particular one on a wide range of conditions.

To select but a few—one may, for example, contrast the light sandy soil of the Bearsted Series in Larkfield Plantation with the Roseacre Series or the Malling Series, each of which has a light surface but a heavy-textured subsoil (Preston and Stanton, 1947). The Roseacre, being rather slow in drainage, differs from the Malling Series, which is absolutely free. This leads logically to the contrast of the moisture conditions of some of these soils. The Bearsted Series holds little water and tends to dry out rapidly, while the alluvial soils in the valley are fed with water from springs, or possess a permanent water table. With both of these one may compare the Malling Series and the Langley Series, which, although perfectly freely drained, have a great capacity to hold moisture because of their depth and their loamy texture. The Barming Series, in spite of its light texture, holds plenty of moisture, too, because of its generous depth.

As a whole, the soils of the Research Station offer plenty of space for root development. The few patches of really shallow soil—the shallow phase of the Chart Series, the eroded phase of the Malling Series, and the shallow phase of the Bearsted Series—occur only in small patches of very limited extent.

There is another contrast of no small importance : the one of soil acidity. Some of the soils of the Bearsted Series are visibly podsolized and show evidence of having been strongly acid in the past, while those of the Barming and Malling Series are naturally acid until the limestone of the rag is nearly reached. Some have a high pH today, but that is entirely the effect of lime applied to the land. The Chart, Wierton, and Medway Series contain a good deal of lime, but their degree of alkalinity does not compare with the alluvial soils in which there is ground water, saturated with lime, not far below the surface.

Such a range of soil conditions should provide excellent scope for experimental work. The only really important group of soils to be found in the district but which is absent on the Station, appears to be a really stiff clay. This might have supplied a badly drained soil without the complication of excess of lime.

Such variety might suggest that it would be difficult to find an even plot upon which to lay out an experiment demanding relative uniformity of soil conditions but, in fact, that is not the case. A large proportion of the land lies upon soils of the Malling and Barming Series. Each of these produces some quite extensive unbroken stretches, but in places they are closely interlocked. Even there it must be borne in mind that they are, in reality, closely related soil series, which offer the roots of crops conditions which are not greatly dissimilar. They produce an almost continuous range intermediate between the two extremes which are taken as typical.

Not only on these, but on the Langley Series, on the Roseacre Series, and on the alluvial soils, there are not inconsiderable blocks of soil of a fair degree of uniformity.

There is one further aspect of the soil picture which is worthy of consideration : namely, to what extent the soils of the Research Station are to be found beyond its boundaries. Some are widespread while others are very local. By far the most important is the Langley Series. Brickearths are found in many parts of Britain and overseas, while in Kent they carry some of the finest fruitgrowing land. There is little of the Brices Series on the Station, but beyond it is fairly widespread.

The sandy soils of the Bearsted and Lowlands Series also occur throughout the long outcrop of the Lower Greensand, and closely resemble the soils of other sand formations besides. The deep sandy loams and fine gravel soils of the Barming Series are typical of considerable stretches of land in the valleys of the larger rivers. The Malling Series is far less widespread and is very local by comparison.

The Chart and Wierton Series are found in small patches throughout the ragstone area, while the soils of the Sandgate Beds are locally distributed because the beds themselves are so capricious. In one spot they give rise to an outcrop of some width, only to vanish almost completely in quite a short space, so that, in total, they comprise a relatively small area. The alluvial soils, too, are very local in distribution.

When all these considerations are weighed up, one cannot help concluding that those who were entrusted with the task of selecting a site for the horticultural research station of Wye College in 1913, before soil series had been devised or the possibility of recognizing soils as individuals envisaged, must have been endowed with shrewd judgment to choose one with so many desirable characteristics. Even when detailed soil maps of the county eventually become available, it will probably not be easy to pick out, from the bewildering array of colours that will adorn it, a territory that would better suit the needs of a research station. Certainly, most of it is good fruitgrowing land, with soils to suit the most fastidious varieties. The greatest part of the land lies upon soils which are deep, well drained, and in the medium range of textures—the three most desirable characteristics in a fruit soil.

SUMMARY OF THE SOIL SERIES AND PHASES FOUND ON THE RESEARCH STATION

Soils of the Ragstone area

(Some soils extend on to the other geological formations in places)

Chart Series.

Greyish, calcareous, medium to heavy loam, derived from the ragstone which usually occurs at less than 30 inches. Well drained.

Chart Series, shallow phase.
Ragstone at 15 inches or less. An eroded soil.

Wierton Series.
Medium to heavy loam passing into hassock (calcareous sand, tinged green with glauconite). Well drained.

Medway Series.
Deep, uniform, greyish drift derived from the Hythe Beds ; fine sandy loam to medium loam. Well drained.

Medway Series, poorly drained phase.
Spring water seeps through the lower layers of the subsoil.

Malling Series.
Deep, warm brown drift over ragstone. Fine sandy loam passing into clay loam with dark ' pug ' layer at bottom. Well drained.

Malling Series, shallow phase.
Ragstone between 18 to 36 inches.

Malling Series, eroded phase.
Ragstone at less than 18 inches.

Barming Series.
Deep, warm brown light loam over ragstone. Sometimes a stiff ' pug ' layer occurs in the lowest part. Well drained.

Barming Series, shallow phase (over ragstone).
Ragstone at less than 36 inches.

Barming Series, shallow phase (over Sandgate Beds).
Sandgate Beds, fine sandy clay, at less than 36 inches.

Barming Series, shallow phase (over Folkestone Beds).
Folkestone Beds, loamy fine sands, at less than 36 inches.

Ditton Series.
Deep, warm brown light loam, similar to that of the Barming Series, but with spring water seeping through the deeper layers of the subsoil.

Langley Series.
Brickearth. Deep, warm brown loam. Well drained.

Langley Series, shallow phase (over Ragstone).
Ragstone at less than 36 inches.

Langley Series, shallow phase (over Sandgate Beds).
Sandgate Beds, fine sandy clay, at less than 36 inches.

Langley Series, shallow phase (over Folkestone Beds).
Folkestone Beds, loamy fine sands, at less than 36 inches.

Brices Series.
Brickearth. Deep, warm brown loam similar to that of the Langley Series, but with spring water seeping through the deeper layers of the subsoil.

Soils of the Sandgate Beds area

Roseacre Series.

Soil of medium depth formed from Sandgate Beds ; fine sandy loam passing into fine sandy clay loam, mottled green and orange-brown. Drainage fairly good.

Stone Hill Series.

Soil of medium depth ; fine sandy loam passing into sandy clay loam. Similar to the Roseacre Series, but mottled colours due to poor drainage occur a little below the top soil and beneath are bright green and orange shades. Poorly drained.

Highworth Series, gravelly phase.

Moderately deep drift soil, brown fine sandy loam passing into fine sandy clay loam, containing a lot of chert gravel. Quite well drained.

Sevington Series.

Moderately deep light loam over fine sandy clay loam (Folkestone Beds downwash over Sandgate Beds). Well drained.

Sevington Series, gravelly phase.

Contains a good deal of flint and chert gravel.

Soils of the Folkestone Beds area

Bearsted Series.

Light loam, passing into yellowish-brown, light loam to loamy sand formed from Folkestone Beds, 24 inches or more deep. Freely drained and poor moisture retention.

Bearsted Series, shallow phase.

Soil less than 24 inches.

Bearsted Series, gravelly phase.

Containing a good deal of flint and chert gravel.

Bearsted Series, shallow gravelly phase.

Lowlands Series.

Deep, light loam Folkestone Beds downwash of uniform greyish brown colour. Freely drained.

Lowlands Series, gravelly phase.

Containing a good deal of flint and chert gravel.

Soils of the Alluvial area in the valleys

Bradbourne Series.

Deep, calcareous stream gravels, sands, and silts with a permanent water table. Grey, fine sandy loam to loam passing into yellow, finely gravelly sands.

Bradbourne Series, improved drainage phase.

An area in which drainage has been improved.

Millhall Series.

Calcareous, alluvial deposit containing numerous white concretions and having a permanent water table. Fairly deep, grey coloured, fine sandy loam over ragstone.

Twisden Series.

Non-calcareous, stream sand and fine gravel in which water seeps through the subsoil. A yellow-brown, fine sandy loam, becoming lighter and finely gravelly in the deeper layers.

SUMMARY

The results are presented of a detailed survey of the soils of the Research Station, designed to provide additional information as to the environmental conditions of the various field trials in progress, and to assist in the lay-out of future trials and in the efficient utilization of the available experimental areas.

The seventeen soil series present are described with notes on their relative suitability for fruit crops ; of the seventeen, three are described for the first time and names proposed.

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SOME ASPECTS OF SOIL VARIATION RELATED TO THE HISTORY AND MANAGEMENT OF THE SOIL

By J. E. GOODE

The recent soil survey.

A detailed soil survey such as that of the Research Station recently completed by Furneaux (1954) is of great value in showing the location and extent of different soil series, and especially so where the description and interpretation of the survey is based on long experience.

The survey will be especially useful in enabling more accurate planning of field experiments and more detailed interpretation of the results, provided it is appreciated, firstly, that the soils described are not distinct entities but merge one into the other as Furneaux has stressed, and, secondly, that a soil survey classifies the soil characteristics observable by sight and touch and that these characteristics are but tentative guides to the properties of a soil as a medium supporting plant growth.

Exchangeable cations, organic matter content, pore size distribution, permeability, hydrogen ion concentration, and many more besides, are all soil characteristics that would be noted and used in soil surveys if they could be determined and classified as readily as colour and texture. Thus it may be said that the soil map indicates the fundamental soil characteristics from the point of view of classification but that, important as these are in relation to soil uniformity, it is highly desirable where field experimental work is concerned to have information on additional soil characteristics.

Experience of the Research Station soils has indicated that history and management of different areas have been so widely different in the past that a soil which is uniform in respect of colour, texture, etc., may be extremely variable in respect of other characteristics, even over quite small areas.

Soil variation arising from the residual effects of previous management.

A striking example of this has arisen on the soil management trial on apples recently laid down in Churchfields West. The pH differs markedly across the trial and can be clearly related to the past husbandry of the area. The trial is mainly situated on the Barming Series, but to the extreme south there is an area of the closely related Malling Series. The river drift soils of the Research Station, principally the Malling and Barming Series, are naturally acid, and high pH values in these soils, provided they are not shallow or eroded phases, indicate previous additions of calcareous materials in quite considerable amounts (Furneaux, 1954).

The soil management trial consists of 60 experimental plots which lie in 10 rows of 6 plots. In 1952 the pH at 0-6 inches and 6-12 inches was determined on single composite samples made up from soil taken from four positions on each plot. A very distinct pH change at row 4 being found, further samples were taken from the south and north ends of these plots. The mean pH of each row of plots for the depth of 12 inches with the pH change across row 4 is shown in Fig. 1.

A tithe map of 1842 shows that the trial area was divided across the present row 4, the southern portion being meadowland and the northern arable. In 1917 the old meadowland was ploughed up and, with the remainder, kept as arable land. Although there are no records between 1842 and 1917, it was known in 1917 that both the meadow and arable portions had been so for many years previously. Thus the soil which was for many years meadowland, now has a low pH, whilst that maintained under continuous arable for a long period has a high pH. In 1918, the northern part of the old arable beyond row 7 was planted with hops which remained until 1942, when the area was grubbed. From 1942 the whole area was managed identically until 1950 when the present soil management trial was commenced. Thus the slight change in pH at row 7 may be the effect of the different management under hops from 1918 to 1942.

In order to determine the correlation between tree growth and pH, the trunk girth for 1950 was used, that is prior to the application of the soil management treatments, when the trees were 5 years old from planting. An analysis of variance carried out on pH in 1952, that is after the soil management treatments had been applied for 2 years, showed that treatments of high and low rates of ammonium sulphate applied at 6 cwt. and 3 cwt. per acre had given rise to differential effects on the pH and it was found necessary to eliminate these effects to avoid errors due to more plots of one treatment than the other lying in any one row. When the effect of treatments had been taken into account there was found to be a marked negative correlation, $r = -0{\cdot}73$ ($P < 0{\cdot}001$) and $r = -0{\cdot}55$ ($P < 0{\cdot}01$), for each of two tree varieties between 1952 pH and 1950 trunk girth (Fig. 1).

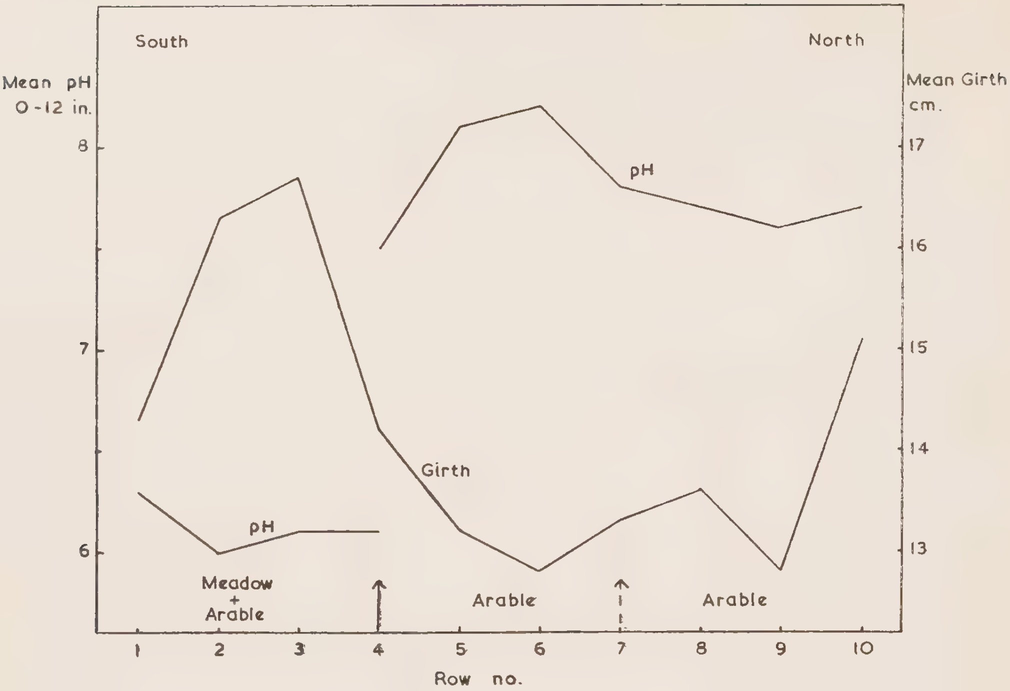

FIG. 1.

Soil pH and tree growth.

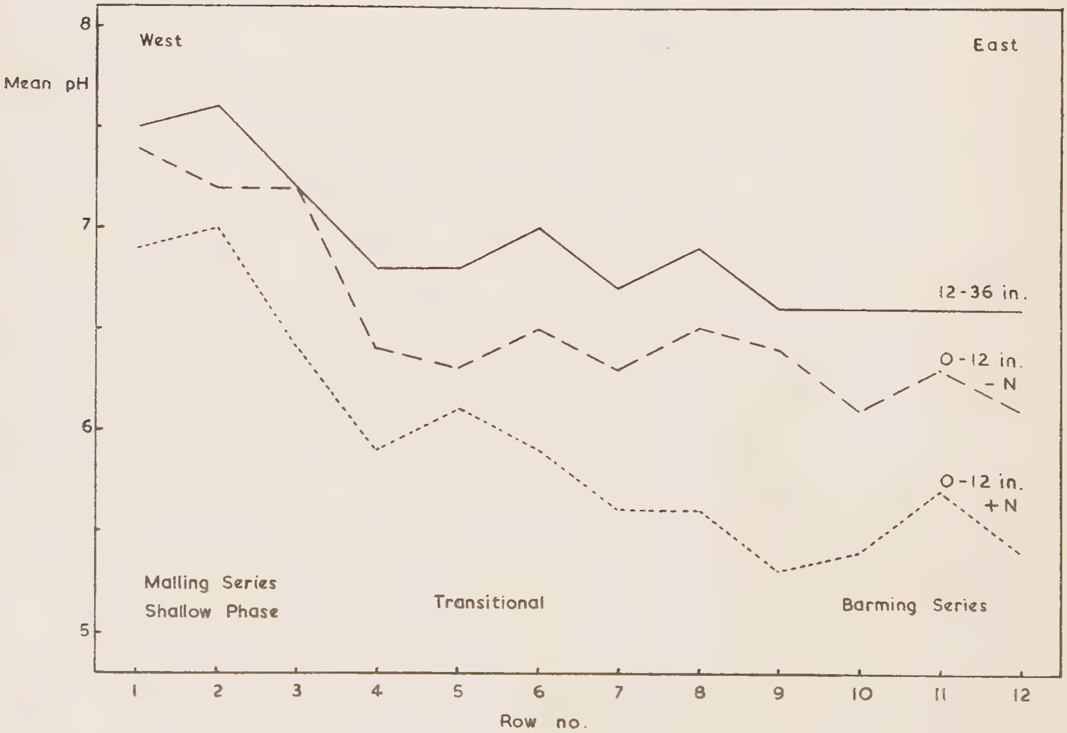

FIG. 2.

The effect of ammonium sulphate on the pH of a related group of soils.

Soil variation arising from experimental treatments.

It is possible, in the course of an experiment, to bring about unintended soil variation by the application of certain treatments. This may occur as the result of either applying a uniform treatment to two or more different soil series within a trial or applying a treatment to some plots and not to others on a soil of one series.

An example is provided by the classic NPK manurial trial on apples of the Research Station (Hoblyn, 1941), which is on a related group of soils but with extremes of that group present. The shallow phase of the Malling Series lies to the west of the trial area and the deeper Barming Series to the east. The former tends to be alkaline whilst the Barming Series shows a moderately low pH throughout its profile. The soil in the centre of the trial can perhaps best be regarded as transitional from Malling to Barming.

The pH of each plot was determined at 6-inch intervals down to a depth of 3 feet, each sample being composed of four borings. It was found that the soil pH below 12 inches depth had been little influenced by any surface manuring treatment; the mean pH of the 12-36 inch borings for each of the 12 rows of plots in the trial illustrate the gradual fall in pH from the shallow Malling through the Malling-Barming transitional zone to the Barming, following the decreasing influence of the underlying calcareous ragstone with increase in soil depth (Fig. 2).

The mean pH of the upper 12 inches of soil of plots receiving ammonium sulphate as a treatment and of those plots not receiving ammonium sulphate has also been shown for each row. Those plots not receiving ammonium sulphate show the acidifying effect of leaching on the upper layers. The application of the ammonium sulphate has resulted in a differential effect on the soil pH, the effect being much more pronounced on the deeper non-calcareous soil than on the shallower calcareous material.

The growth of the trees on the soil management trial previously described has indicated a possible relationship between growth and pH. Thus the ammonium sulphate used in the manurial trial just described may be introducing a differential effect on tree growth due to its influence on the soil pH. In other words, when ammonium sulphate is used as the source of nitrogen, the nitrogen treatment is accompanied by a pH effect which, unfortunately, is not uniform across the trial. The less vigorous growth of the trees to the west of this trial has been accounted for by the difference in soil depth, probably quite correctly, but the new evidence suggests that a pH effect cannot be ruled out.

Discussion.

The detailed records of tree behaviour, both in growth and cropping, being accumulated in the course of field experiments at East Malling provide a wide field for study, not only of the direct effects of soil type and characteristics, but also of the interaction of the latter with experimental treatments. The detailed soil survey carried out by Furneaux has provided the basis that will enable such studies to be related to the varying gradations of soil found on the Station.

Attention has been drawn to the inherent limitations of the soil survey method in the preceding paper. The examples quoted in this note illustrate the great importance of interpreting a soil survey in the light of the differential effects of local variations in the cultural and experimental history of the land. Studies to this end are being developed, not only in the hope of achieving greater efficiency in the lay-out and interpretation of field trials on the Station, but also as a contribution to a better understanding of the part played by the soil in the growth and cropping of fruit crops.

Summary.

A soil, uniform in respect of the fundamental characteristics used for classifying the soil in a survey, may show marked variation in respect of tree growth due to differences in one or several soil factors not included in the classification.

An example is described in which the soil pH is markedly different across an area of soil relatively uniform in respect of the fundamental characteristics. The variation in pH has been related to differences in past management of the area. The significance of this variation on tree growth is shown.

The possible effect of experimental treatments, differentially applied over trial areas, on soil factors other than those intended to be modified by the treatment is also discussed.

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A DESCRIPTION OF CERTAIN M.IX CROSSES

By H. M. TYDEMAN

The apple rootstocks now known as the ' M.IX Crosses ' were raised by the writer in 1929 from crosses between M.IX and ten other members of the Malling rootstock series (Tydeman, 1933). By successive selections based on field and nursery performance the seedlings were reduced from over one thousand to eighteen (Tydeman, 1943) and later to six (Preston, 1954). The pomological interest of these six rootstocks justifies further study ; none has so far been released either in the United Kingdom or overseas. Their parentages are as follows:

3426.	M.VII	×	M.IX.
3428.	M.IX	×	M.VII.
3430.	M.XII	×	M.IX.
3431.	M.XIII	×	M.IX.
3436.	M.XVI	×	M.IX.
3438.	M.IX	×	M.XII.

The descriptions which follow are based on the one-year vegetative shoots from the stools, and are presented in a similar form to that used for describing the Malling-Merton series (Tydeman, 1953). In Tables I and II will be found the descriptions of the various characters of the vegetative shoots in summer and winter respectively and these are illustrated in Figs. 1 to 9. The average dimensions of certain of the characters are summarized in Tables III and IV. The separation of the six stocks should not be found difficult as each has distinctive features, the most conspicuous of which have been set out in Table V.

Acknowledgement.

The writer's thanks are due to Mr. E. Yoxall Jones who took the photographs.

Summary.

Descriptions and illustrations are given of six new apple rootstocks selected from crosses between M.IX and M.VII, M.XII, M.XIII, and M.XVI.

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Table I.

SUMMER CHARACTERS

	3426.	3428.	3430.	3431.	3436.	3438.
General habit.						
Growth	Not very vigorous, spreading; shoots slender and flexible.	Vigorous, spreading, long, slender, flexible shoots.	Vigorous, spreading, long, slender, flexible shoots.	Rather weak, spreading; thin, flexible shoots.	Fairly vigorous; slender, rather stiff shoots.	Fairly vigorous, erect; shoots slender and rather stiff.
Feathering	Little.	Little.	Some.	Little.	Little.	Little.
Number of shoots on stools ..	Not very prolific.	Prolific.	Prolific.	Not very prolific.	Fairly prolific.	Fairly prolific.
Wood.						
Colour	Deep chocolate brown.	Bright reddish brown.	Chocolate brown.	Bright chocolate brown.	Chocolate brown with a distinct silvery sheen.	Dull greenish brown with a slight silvery sheen.
Hairiness	Covered with a faint whitish pubescence.	Covered with a fine whitish pubescence.	Covered with a fine whitish pubescence.	Covered with a very thin whitish pubescence.	Covered with a very thin whitish pubescence.	Covered with a slight whitish pubescence.
Texture	Smooth and shiny.	Distinctly striated.	Faintly striated.	Distinctly grained.	Finely grained.	Finely grained.
Lenticels.						
Number	Few.	Few.	Few.	Few.	Fairly numerous.	Fairly numerous.
Conspicuousness	Conspicuous, small.	Conspicuous, small.	Conspicuous, large.	Conspicuous, medium.	Fairly conspicuous, small.	Not very conspicuous, small.
Shape and colour	Oval, dull yellowish brown.	Round, yellowish brown.	Oval, deep orange.	Oval, yellowish brown.	Oval, yellowish brown.	Oval, dull orange brown.
Leaves.						
Size	Medium.	Medium.	Medium to large.	Smallish.	Small to medium.	Medium to large.
Shape	Medium ovate.	Medium ovate.	Broadly oval.	Medium oval.	Medium oval.	Medium to broadly ovate.
Base	Rounded.	Rounded.	Flattish.	Rounded.	Broadly wedge-shaped.	Rounded.
Apex	Gradually tapering, much drawn-out, down-turned.	Gradually acuminate, tips much drawn out.	Abruptly acuminate	Abruptly acuminate, slightly drawn out.	Gradually acuminate, slightly twisted.	Gradually acuminate, tips somewhat drawn out.
Serrations	Finely and acutely serrate.	Regularly serrate.	Finely and acute serrate.	Acutely serrate.	Finely and acutely serrate.	Finely and acutely serrate.
Surface	Very shallowly upfolded, often flat, slightly crinkled.	Flat, often slightly convex.	Shallowly upcup	Deeply upfolded.	Shallowly upfolded.	Shallowly upfolded.
Margin	Slightly undulating.	Slightly undulating.	Raised and undulating.	Raised and waved.	Undulating.	Raised and shortly waved, giving a frilled appearance.
Pose in relation to stem ..	Horizontal.	Upturned.	Horizontal or sligh upturned.	Much upturned.	Much upturned.	Slightly upturned.
Colour	Deep green, fairly glossy.	Bright green.	Deep green, fair glossy.	Dull green.	Deep bluish green, not very glossy.	Deep green, upper surface rather dull.
Hairiness on under surface ..	Covered with short, pale hairs.	Sparsely hairy.	Fairly woolly.	Fairly hairy.	Some short pale hairs.	Some short pale hairs.
Texture	Thin and papery.	Thin and papery.	Crisp and papery.	Smooth and crisp.	Crisp and papery.	Crisp and papery.
Colour of tips of shoots ..	Silvery green, edged with bronze.	Much bronzed.	Pale whitish gree with pinkish woo	Pale green, slightly bronzed.	Pale green, distinctly bronzed.	Whitish green, slightly bronzed.
Leaf stalk.						
Shape	Slender, channelled.	Slender, channelled.	Slender, channelled.	Slender, channelled.	Slender, shallowly channelled.	Slender, shallowly channelled.
Length	Rather short.	Fairly long.	Fairly long.	Fairly long.	Medium length.	Fairly long.
Colour	Slightly tinged deep red.	Tinged deep wine red, slightly pubescent.	Tinged deep wine red, slightly pubescent.	Deeply tinged wine red, extending up the lamina.	Tinged bright wine red.	Tinged deep wine red, slightly pubescent.
Pose	Upturned.	Much upturned.	Out-turned.	Much upturned.	Much upturned.	Much upturned.
Stipules.						
Size	Small.	Smallish.	Smallish.	Small.	Fairly small.	Fairly large.
Margin	Slightly serrate.	Faintly serrate.	Entire.	Faintly serrate.	Distinctly serrate.	Distinctly serrate.
Shape	Lanceolate.	Crescent-shaped.	Narrowly lanceolate, shortly petiolate.	Crescent-shaped, shortly petiolate.	Irregularly lanceolate.	Crescent-shaped or lanceolate.
Pose	Spreading.	Spreading or slightly upturned.	Horizontal, fairly close together.	Erect.	Upturned.	Horizontal, rather spreading.
Season of leaf-break.	Early.	Early.	Early.	Early.	Late.	Midseason.
Time of defoliation.	Late.	Late.	Intermediate.	Very late.	Late.	Fairly late.
Colour of foliage in autumn.	Light khaki brown.	Bright green, turning to crimson and brown.	Bright glossy green.	Medium green, leaf-margins turning brown.	Bluish green, often edged with bright red, changing to deep yellow.	Dark green, often lined with yellow along the veins with occasional purple patches.

Table II.

WINTER CHARACTERS.

	3426.	3428.	3430.
General habit.			
Strength of growth	Not very vigorous.	Vigorous.	Vigorous.
Habit of growth	Spreading.	Spreading.	Spreading.
Number of laterals	Few.	Very few.	Rather numerous.
Wood.			
Stoutness	Slender.	Rather slender.	Fairly slender.
Flexibility	Very flexible.	Fairly flexible.	Fairly flexible.
Internodes	Of medium length, fairly straight, somewhat swollen at the nodes.	Rather short, somewhat zigzagged.	Fairly long, slightly zigzagged.
Colour	Deep chocolate brown with greenish patches.	Bright reddish brown, green towards the base.	Chocolate to greyish brown.
Hairiness	Some pale waxy pubescence.	Covered with a slight pale pubescence.	Some whitish pubescence.
Texture	Very smooth and shiny.	Distinctly striated.	Finely ridged and grained.
Lenticels.			
Number	Few.	Few.	Few.
Distribution	Scattered.	Scattered.	Scattered.
Size	Small, indistinct.	Smallish, distinct.	Often fairly large.
Colour	Pale yellowish brown.	Yellowish brown.	Deep reddish orange.
Shape	Rounded.	Rounded.	Oval.
Buds.			
Size	Small.	Small.	Smallish.
Shape	Oval-triangular, somewhat flattened.	Triangular, with a fairly acute apex.	Oval-triangular, with a rounded, obtuse apex.
Compactness	Inclined to be ragged.	Compactly wrapped.	Slightly ragged at the edges.
Colour	Pale ashen grey.	Pale ashen grey with smoky red patches.	Deep smoky grey, flecked with pale ashen grey and sooty red.
Hairiness	Covered with fine silvery hairs.	Covered with fine silvery hairs.	Covered with fine silvery hairs.
Pose	Closely adpressed to shoot.	Closely adpressed to shoot.	Inclined to point outwards.
Base	Little extended and slightly clawed.	Little extended but distinctly grooved.	Somewhat extended and clawed, rather pointed.

3431.	3436.	3438.
Rather weak.	Fairly vigorous.	Fairly vigorous.
Spreading.	Rather spreading.	Erect.
Very few.	Very few.	Few.
Slender.	Rather slender.	Slender.
Flexible.	Stiff and wiry.	Stiffish and wiry.
Short, slightly zigzagged.	Fairly short and straight.	Short and fairly straight, somewhat swollen at the nodes.
Deep chocolate brown.	Deep chocolate brown with a distinct silvery sheen.	Deep purplish brown, often green below, with a slight silvery sheen.
A little pale pubescence.	Covered with a fine wax-like pubescence.	A little pale pubescence.
Distinctly longitudinally grained and striated.	Finely grained.	Finely grained.
Few.	Fairly numerous.	Fairly numerous.
Scattered.	Scattered.	Mostly towards the base.
Smallish, indistinct.	Small, indistinct.	Smallish, not conspicuous.
Pale yellow brown.	Pale yellowish brown.	Dark reddish brown.
Rounded.	Rounded.	Oval.
Smallish.	Smallish.	Small.
Broadly oval-triangular, with an acute apex.	Oval-triangular, plump, with an obtuse, rounded apex.	Triangular, rather flattened, with a fairly acute apex.
Slightly ragged at the edges.	Compactly wrapped.	Compactly wrapped.
Deep sooty grey with patches of brownish red.	Dark smoky red with patches of ashen grey.	Dark sooty grey with patches of dull red.
Some fine silvery hairs.	Some fine hairs.	Some fine hairs.
Closely adpressed to shoot.	Often slightly outturned.	Closely adpressed to shoot.
Little extended, slightly clawed.	Only slightly extended but clawed and ridged.	Somewhat extended and clawed, rather pointed.

TABLE III.

DIMENSIONS OF VARIOUS FOLIAGE CHARACTERS.

(Averages of one hundred observations.)

Rootstock.	LEAF BLADE.						LEAF STALK.		STIPULES.			
	Length. mm.	Breadth. mm.	Breadth expressed as a % of length.	Length of leaf tip. mm.	Expressed as a % of length of leaf blade.	Number of serrations.	Length. mm.	Expressed as a % of length of leaf blade.	Length. mm.	Expressed as a % of length of leaf stalk.	Breadth. mm.	Expressed as a % of length of stipule.
3426	69	43	62	8	12	94	18	26	5	28	1	20
3428	66	43	65	9	14	67	19	29	8	42	1	13
3430	71	56	79	6	8	99	20	27	8	40	1	13
3431	53	38	72	5	9	72	16	30	5	31	1	20
3436	58	39	67	6	10	88	14	24	6	43	1	17
3438	79	60	76	10	13	104	23	29	14	61	3	21

TABLE IV.

DIMENSIONS OF CERTAIN CHARACTERS ASSOCIATED WITH THE SHOOTS DURING DORMANCY.

(Averages of fifty observations.)

Rootstock.	DIAMETER OF SHOOTS.					DIMENSIONS OF BUDS.				Length of internode. mm.	Lenticels—number per centimetre of shoot.
	Between the buds. mm.	Across the buds. mm.	Percentage increase.	Through the buds. mm.	Percentage increase.	Length. (L) mm.	Breadth. (B) mm.	Length expressed as a % of breadth.	Size. $(\frac{1}{2}LB)$ sq.mm.		
3426	4·8	5·5	15	6·2	29	3·0	3·5	86	5	25	3
3428	6·7	7·3	9	8·0	19	2·9	3·6	80	5	24	3
3430	7·2	7·7	7	9·1	26	3·6	4·0	90	7	27	4
3431	4·1	4·4	7	5·0	22	3·4	3·3	103	6	24	2
3436	5·7	6·1	7	7·0	23	3·3	3·9	85	6	23	8
3438	5·4	5·9	9	7·0	30	2·8	3·3	85	5	23	8

Table V.

DISTINCTIVE CHARACTERS OF SIX M.IX CROSSES.

	In Summer.	In Winter.
	One-year shoots stiff and wiry.	
3436	Smallish, medium oval, deep bluish green leaves with wedge-shaped bases and small, lanceolate, erect stipules.	Fairly vigorous stools with spreading, chocolate brown shoots with a distinct silvery sheen ; fairly numerous, indistinct, pale yellowish brown lenticels ; smallish, blunt, smoky red, slightly out-turned buds.
3438	Shoots with inconspicuous, small, orange brown lenticels; largish, broad leaves with frilled, finely serrate margins and large, broad, serrate stipules.	Fairly vigorous stools with erect, deep purplish brown shoots often green towards the base ; fairly numerous, small, brownish red lenticels ; smallish, rather flattened, acutely pointed, greyish, closely adpressed buds with extended and pointed bases.
	One-year shoots slender and flexible.	
3426	Deep chocolate brown, smooth, shiny shoots with medium ovate, rather flat, slightly crinkled, fairly glossy leaves with much drawn-out, down-turned tips ; rather short, upturned petioles and small, lanceolate, serrate stipules.	Deep chocolate brown, slender, smooth and shiny shoots with few, indistinct, small, yellowish lenticels and small, somewhat flattened, ashen grey, rather ragged buds.
3428	Bright grass green, flattish, upturned leaves and much upturned petioles ; small, faintly serrate, crescent-shaped stipules.	Bright reddish or greenish brown, distinctly striated shoots with shortish internodes and small, pointed, ashen grey, adpressed buds distinctly grooved beneath.
3430	Shoots with large, deep orange lenticels ; dark green, glossy, horizontal leaves with out-turned petioles ; smallish and entire, lanceolate stipules.	Somewhat feathered, chocolate or greyish brown, ridged and grained shoots with longish internodes ; few, fairly large, reddish orange lenticels ; blunt, somewhat ragged, slightly protruding buds.
3431	Weak, spreading shoots with smallish, deeply upfolded and upturned leaves ; upturned petioles and small, faintly serrate, crescent-shaped stipules.	Rather weak, deep chocolate brown shoots, distinctly longitudinally grained, with few, yellowish brown lenticels and small, pointed, greyish, slightly ragged, adpressed buds.

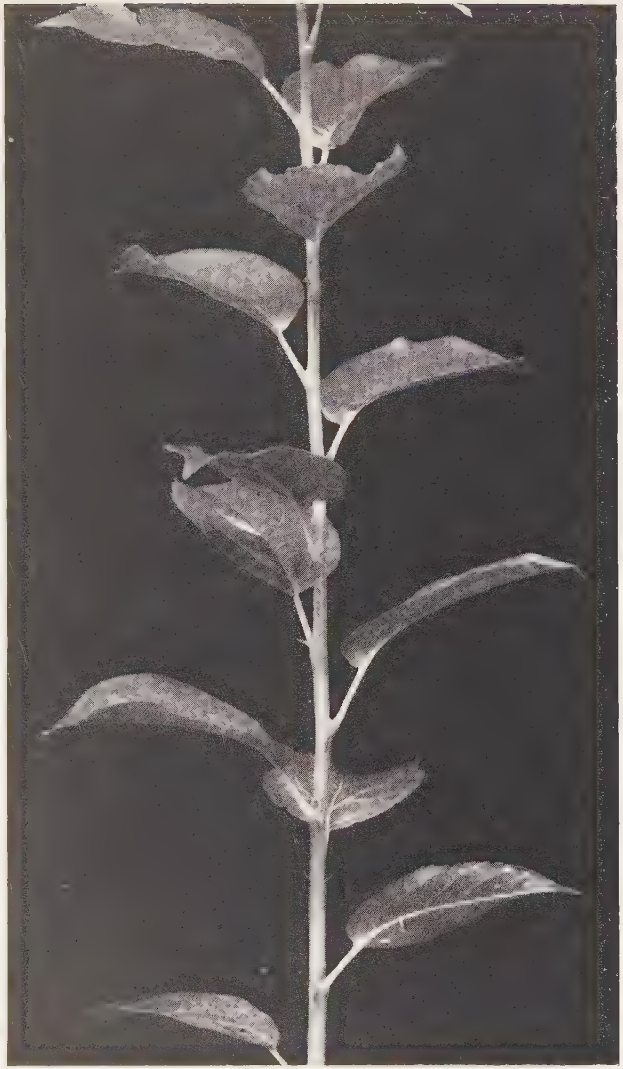

FIG. 1.

3426. Medium ovate, rather flat, slightly crinkled, glossy leaves with much drawn out, downturned tips and rather short, upturned petioles.

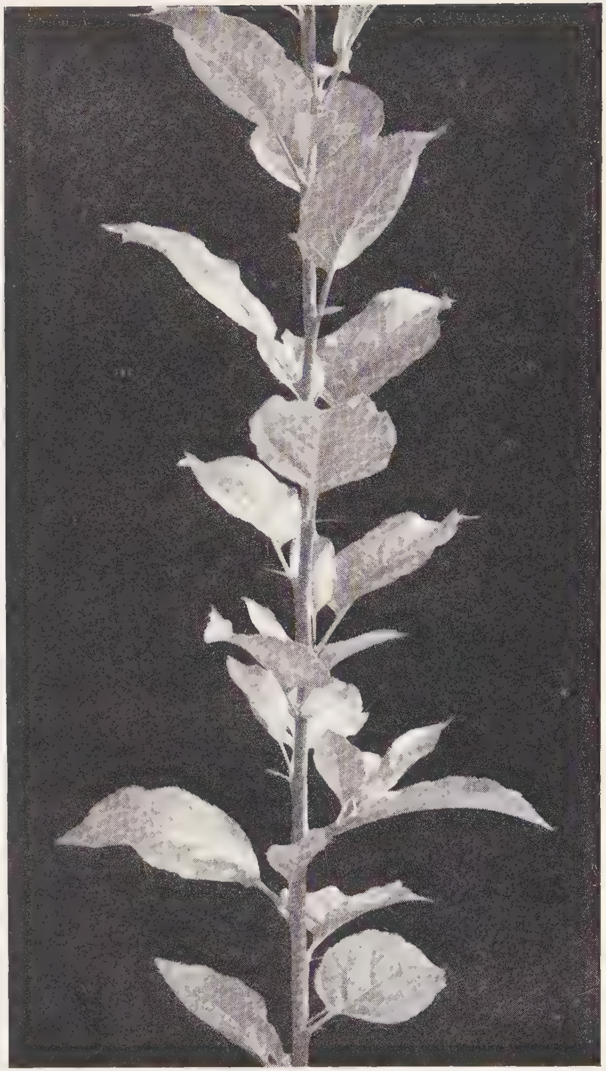

FIG. 2.

3428. Bright grass green, flattish, upturned leaves with much upturned petioles and small, faintly serrate, crescent-shaped stipules.

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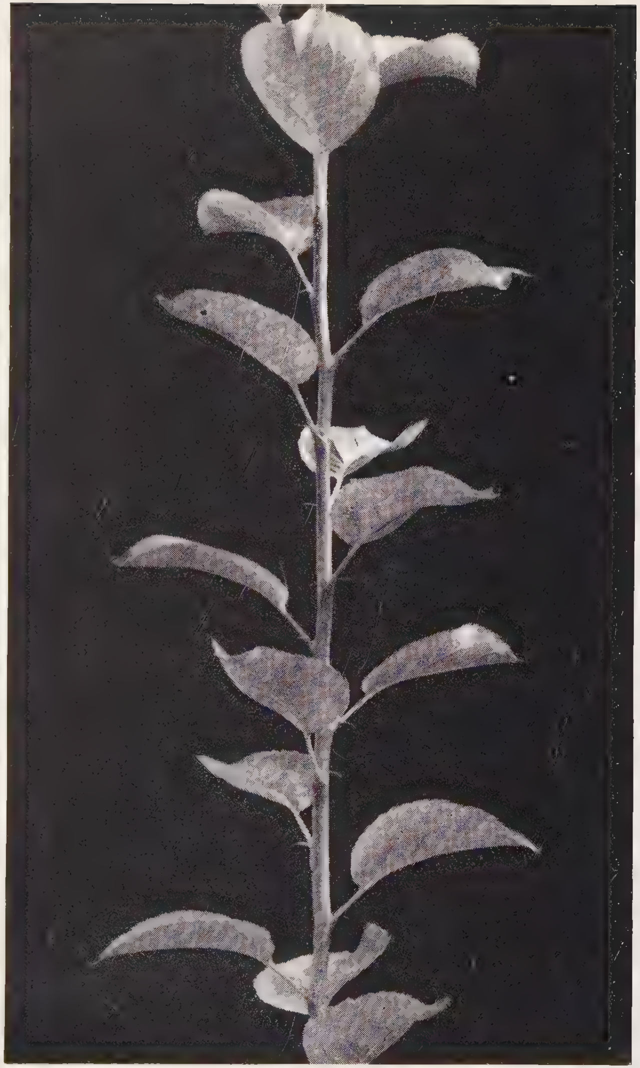


Fig. 3.

3430. Dark green, glossy, horizontal leaves with out-turned petioles, smallish, entire, lanceolate stipules; and few, fairly large, reddish orange lenticels.

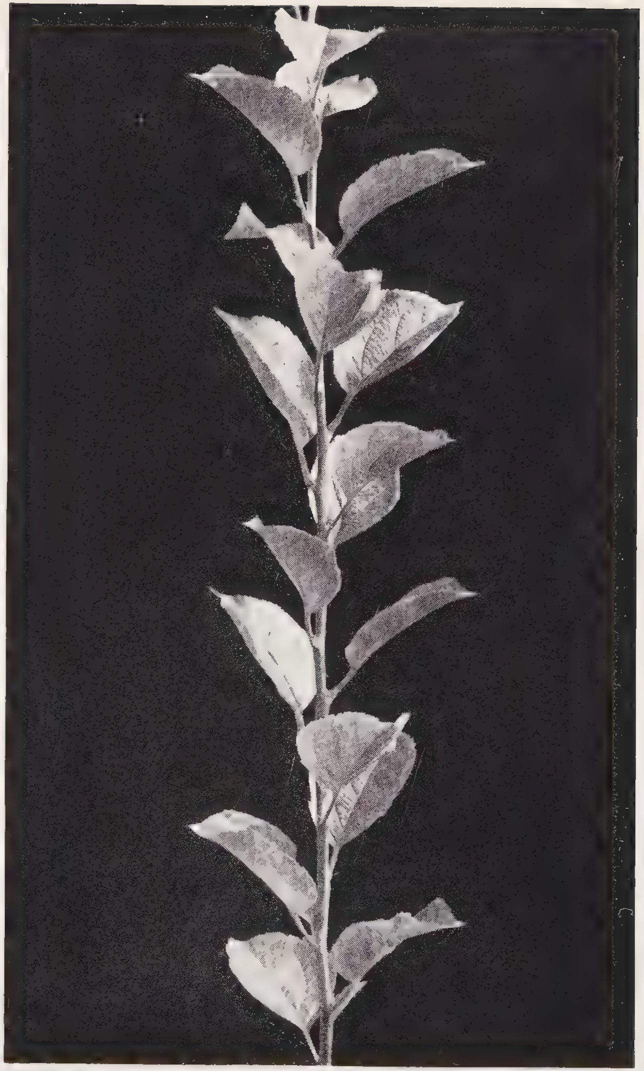


Fig. 4.

3431. Smallish, deeply upfolded and upturned leaves with upturned petioles and small, faintly serrate, crescent shaped stipules.

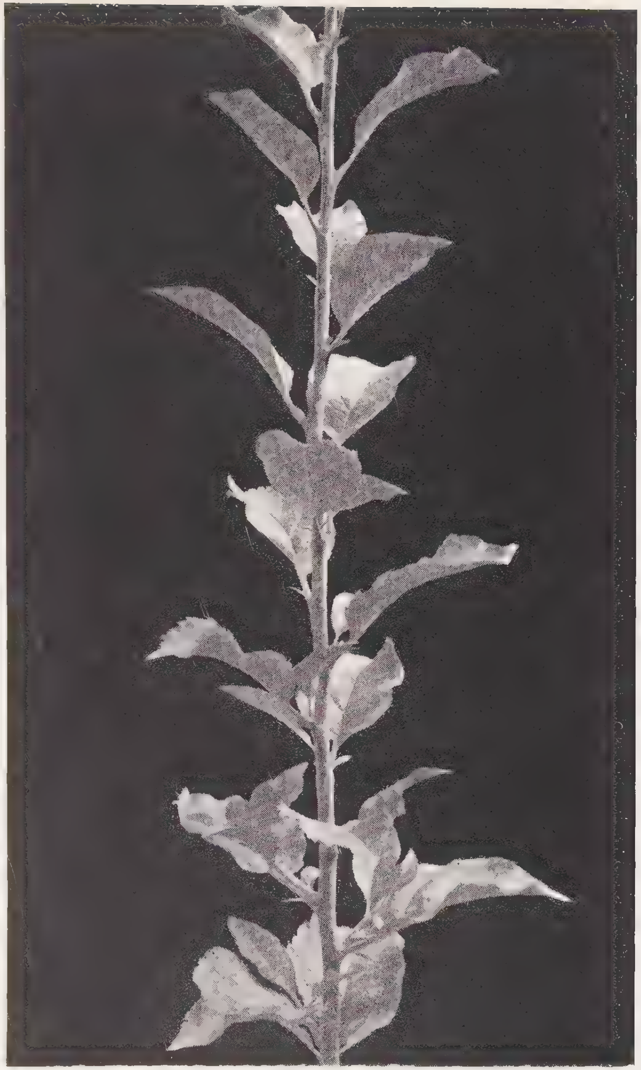


FIG. 5.

3436. Medium oval, bluish green leaves with wedge-shaped bases and small, lanceolate, erect stipules.

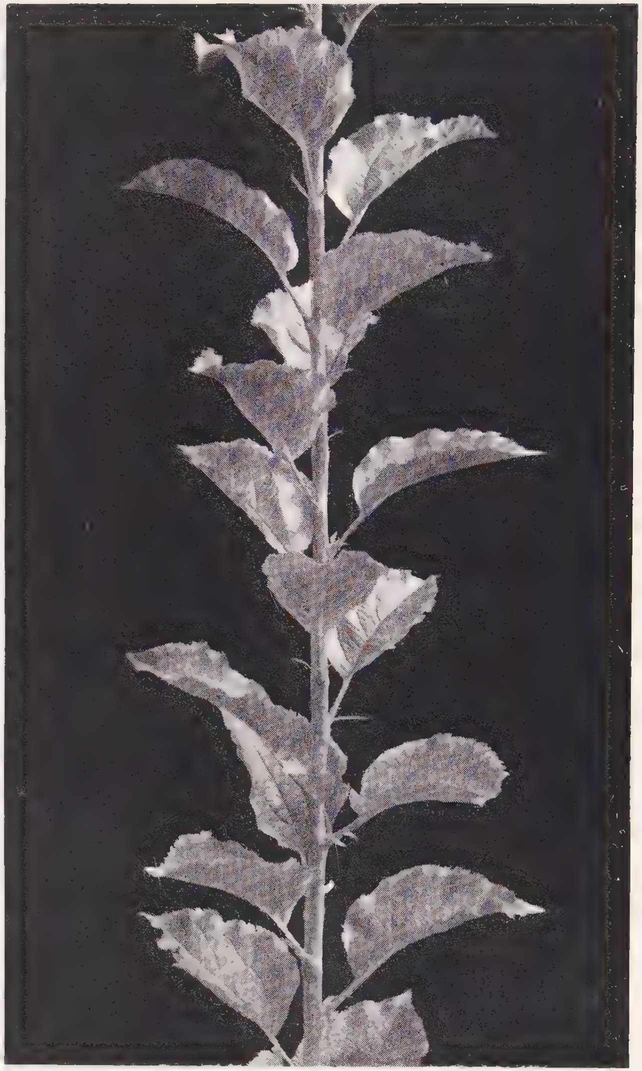
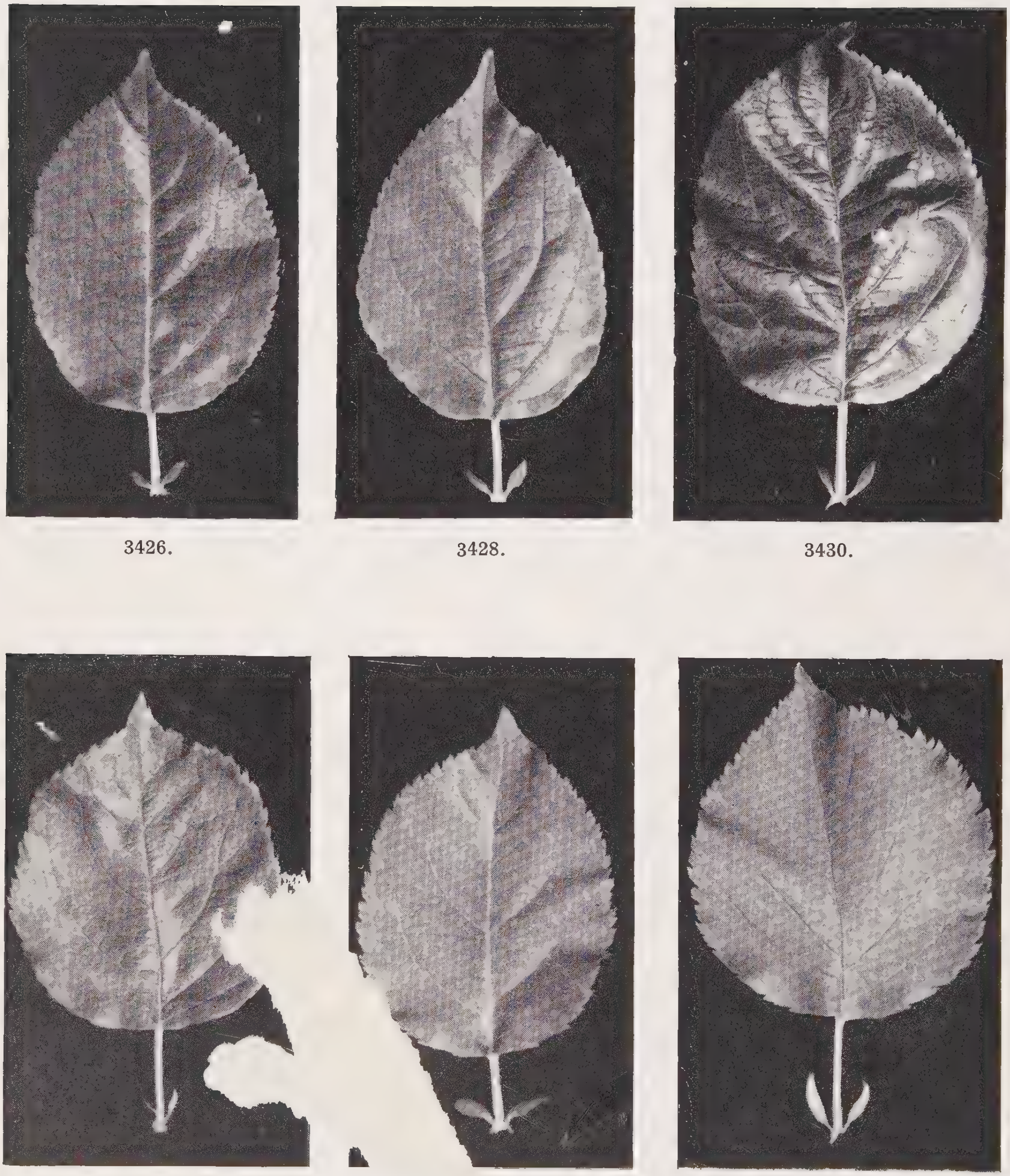


FIG. 6.

3438. Largish, broad leaves with frilled edges, fine serrations, and large, broad, serrate stipules.

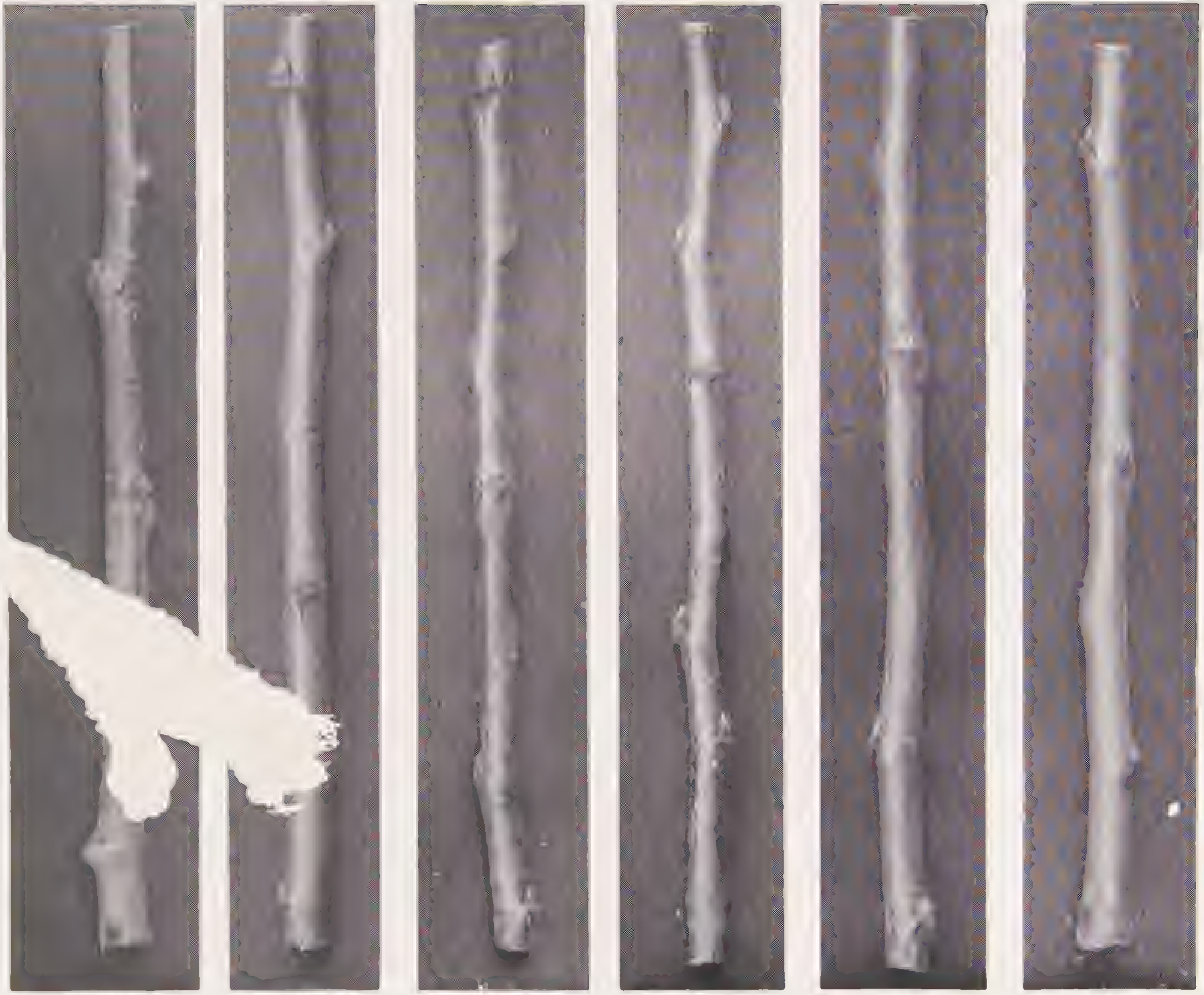


3426. 3428. 3430.

3431. 36. 3438.

FIG. 7.

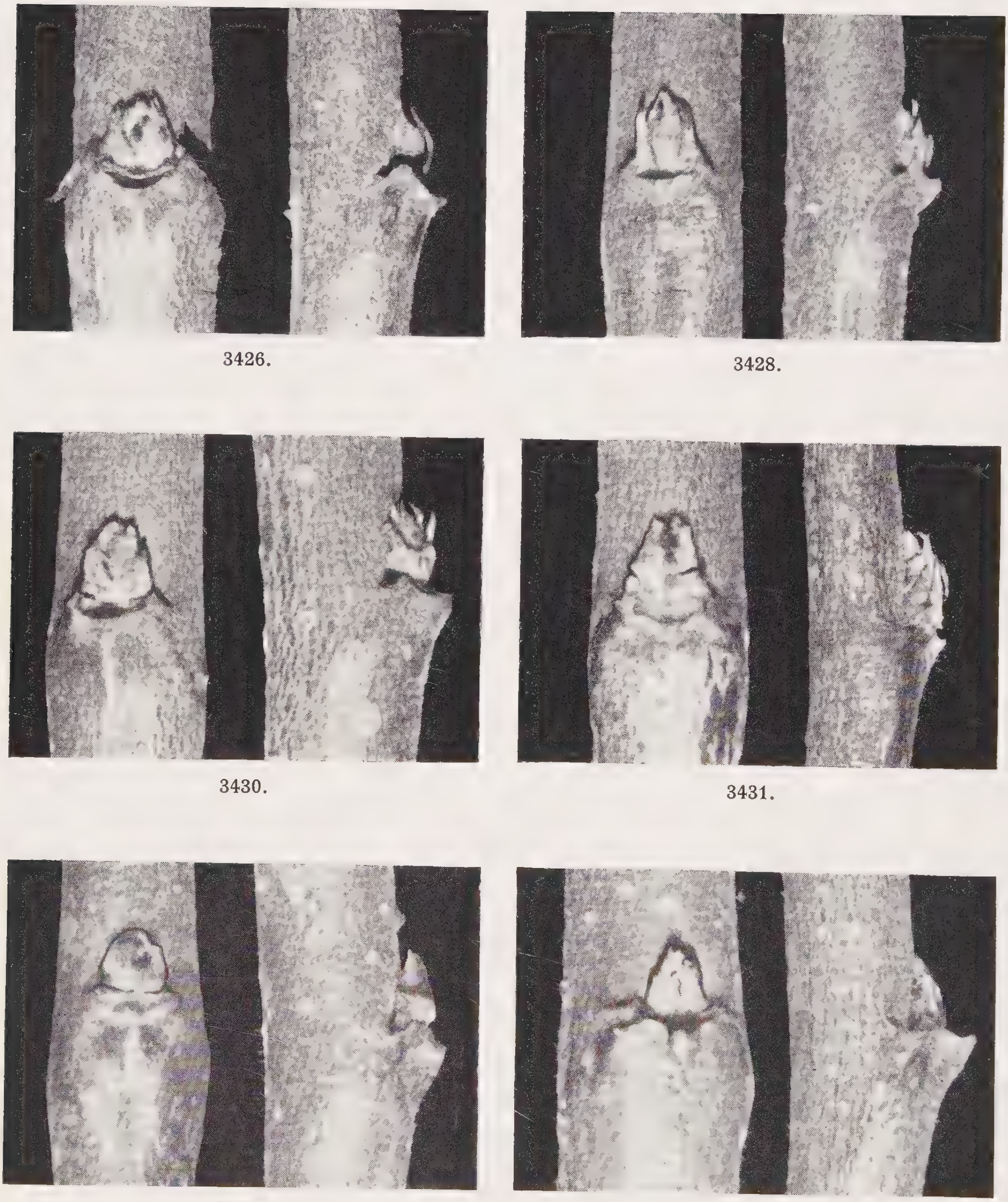
Leaves of certain M.IX crosses.



3426. 3428. 3430. 3431. 3436. 3438.

FIG. 3

Dormant shoots of certain M.IX. crosses.



3426. 3428.

3430. 3431.

3436. 3438.

Fig. 9.

Nodes and buds (enlarged) of certain M.IX crosses.

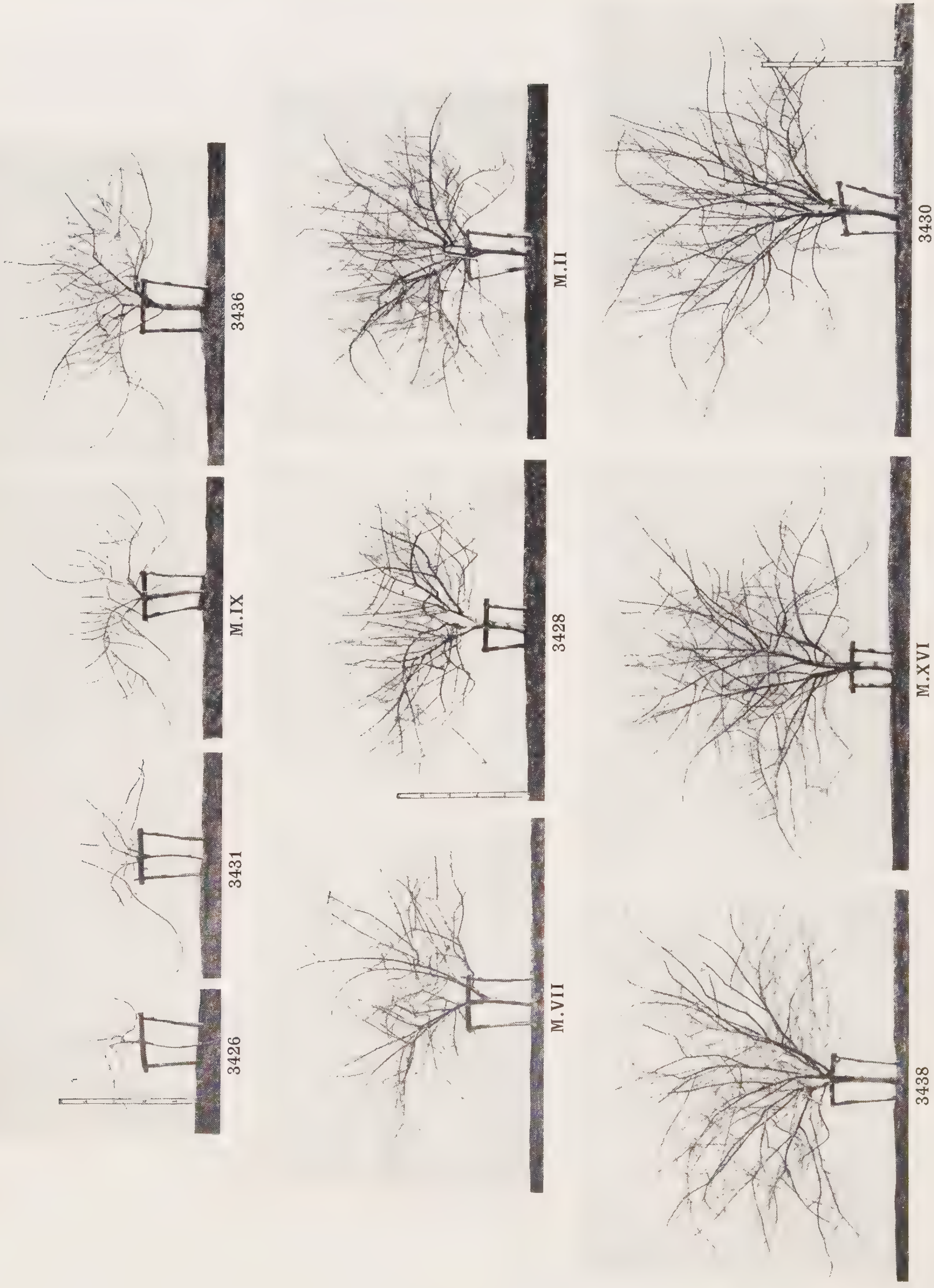

3438
M.XVI
3430
M.VII
3428
M.II
3426
3431
M.IX
3436

FIG. 1.

Eight-year-old trees of Cox's Orange Pippin on six rootstocks from the M.IX Crosses and four Malling rootstocks, showing differences in tree size.

APPLE ROOTSTOCK STUDIES: THE M.IX CROSSES

By A. P. PRESTON

In 1929, families of apple rootstocks were raised at East Malling having M.IX as a common parent, the other parents being other Malling rootstocks (Tydeman, 1933).

By using the dwarfing rootstock M.IX as a common parent it was hoped that its precocious habit might be combined with the vigour of other rootstocks, and that an improvement on M.IX itself might be found among the seedlings. From the crosses obtained approximately one thousand seedlings were raised and propagated vegetatively by the stooling method. After nursery trials eighteen clones were selected for field trial as potential rootstocks. Their parentage is given in Table I and this paper presents the first results of these field trials.

Material and methods.

In 1945 the rootstocks, which had been provisionally grouped for vigour by Tydeman (1943), were worked to scion varieties. The one-year-old trees were planted in three trials during the winter of 1946 on a drift soil of the Malling Series of sandy loam texture (see Preston and Stanton, 1947 ; Furneaux, 1954).

All the trials were clean cultivated until mid-July each year, when autumn weeds were allowed to grow. The trees have been lightly pruned by the regulated method ; this has brought most of them into early and relatively heavy bearing, but has not proved an altogether satisfactory treatment for trees on the very dwarfing rootstocks.

Trial A.

This consisted of rootstocks thought likely to have a dwarfing effect. Plots of four trees on each rootstock, two of Cox's Orange Pippin and one each of Sunset and Orleans Reinette, were set out in four randomized blocks. Trees on M.IX and M.VII were included as controls.

Trial B.

This consisted of rootstocks considered likely to produce trees of intermediate vigour. Six-tree plots, consisting of three trees of Cox's Orange Pippin and one each of Orleans Reinette, Egremont Russet, and Ribston Pippin were arranged in three randomized blocks. Trees on M.IV, M.VII, and M.II were used as controls.

Trial C.

This consisted of rootstocks likely to produce vigorous or very vigorous trees. The scion varieties and plot lay-out were the same as for Trial B. The controls were trees on M.II, M.XVI, and Malling Crab C.

Results.

Vigour.

Early wood growth records were later replaced by an annual record of weight of prunings ; this supplemented trunk girth, recorded annually nine inches above the union as a vigour record. The data from these two measurements agree very well and show a wide range of vigour amongst trees on the new rootstocks (Tables I and II). The data for mean trunk girth have been analysed statistically and show rootstocks to differ significantly in their effects (Table I). It is clear, however, that rootstocks 3432, 3435, and 3437 in Trial C, originally classified on the information then available as likely to induce vigour, should now be regarded as dwarfing or intermediate. Similarly, rootstocks 3420, 3421, and 3423 in Trial B should be regarded as dwarfing.

Suckering propensity.

The variation in the suckering propensity of trees on the new rootstocks has been an outstanding feature of the trials. Annual records of suckering show that there is a distinct association between the vigour of the tree and degree of suckering, trees on dwarfing rootstocks suckering more than those on the more vigorous ones. Trees on the dwarfing rootstock 3431 proved to be the important exception

TABLE I.

PARENTAGE OF NEW ROOTSTOCKS, AND THE VIGOUR AND SUCKERING PROPENSITY OF TREES WORKED ON THEM COMPARED WITH THOSE ON SOME MALLING ROOTSTOCKS

Trial.	Root-stock.	Parentage : Malling rootstocks.	Vigour.		Suckering data, 1948–52.			
			Mean trunk girth (cm.) 1952.	*Sig. ratio** (*P*=0·05).	Percentage of trees suckering.	No. of years in which suckering recorded.	Mean number of suckers per tree each year.	Vigour of suckers : 1=weak 3=strong.
A	3426	VII×IX	7·0	*1·06*	87	5	3·8	1·8
	3424	IX×V	8·9		100	5	5·1	2·0
	3431	XIII×IX	9·2		0	0	0·0	0·0
	3413	II×IX	9·2		87	5	2·5	1·6
	3419	IX×IV	11·0		61	4	3·0	1·7
	M.IX		12·0		26	3	1·5	1·3
	341	I×IX	18·2		25	2	1·5	2·1
	M.VII		19·9		12	3	1·0	1·3
B	3421	V×IX	9·4	*1·11*	100	5	4·2	1·9
	3423	IX×V	10·0		88	5	2·9	1·9
	3420	V×IX	10·3		82	5	3·0	2·0
	3422	V×IX	13·7		72	5	2·3	2·1
	3436	XVI×IX	16·0		11	2	1·0	1·5
	M.VII		20·7		22	4	2·6	1·1
	M.II		21·0		5	1	1·0	3·0
	3428	IX×VII	21·2		11	1	1·0	1·0
	M.IV		22·8		16	4	2·1	1·6
C	3435	IX×XV	12·5	*1·11*	66	5	2·0	1·9
	3432	IX×XIII	15·1		16	2	1·6	2·3
	3437	V×IX	15·7		83	5	2·4	1·9
	3414	II×IX	19·5		27	3	1·0	1·8
	M.II		20·1		5	1	1·0	1·0
	3438	IX×XII	23·5		5	1	1·0	3·0
	M.XVI		24·4		0	0	0·0	0·0
	Crab C		25·1		0	0	0·0	0·0
	3430	XII×IX	26·9		0	0	0·0	0·0

* Analysis on trunk girth was carried out on log girth. Significant *differences* between the log girths of two rootstocks are transformed into significant *ratios* when the data are transformed back into girths.

TABLE II.

MEAN TOTAL WEIGHT OF PRUNINGS PER TREE (LB.), 1949-52.

Trial A									
	3424	**3431**	3426	3413	3419	M.IX	341	M.VII	
	0·5	0·5	0·7	0·9	1·1	1·4	3·0	4·5	
Trial B									
	3421	3420	3423	3422	**3436**	M.II	**3428**	M.VII	M.IV
	0·4	0·5	0·7	1·1	2·2	4·6	4·9	4·9	6·7
Trial C									
	3435	3437	3432	3414	M.II	M.XVI	**3438**	Crab C	**3430**
	1·0	1·8	1·9	3·5	3·8	5·2	5·6	7·7	9·6

in this respect. The percentage of trees that have suckered on each rootstock is given in Table I and the figures in the last three columns of this table give an indication of the severity of suckering. Data show the effect of rootstock to be paramount ; the scion variety appears to have had no very great effect (Table III). Partial excavation of the root system of a tree on the very dwarfing rootstock 3424 showed that the majority of suckers arose from the base of the rootstock stem, but some suckers were also observed growing from unbroken roots. Recent observations on the nursery behaviour of these rootstocks show that the suckering propensity of a rootstock can now be determined in the initial stages of nursery selection, and such types discarded.

Table III.

Effect of variety on vigour and suckering (mean of all rootstocks).

	Cox's Orange Pippin.	Orleans Reinette.	Ribston Pippin.	Egremont Russet.	Sunset.
Cross-sectional area of trunk in sq. cm., 1952	25·4	26·5	27·3	24·9	11·7
Percentage of trees suckering	35	44	44	33	40

Fruit buds.

The number of fruit buds per tree was recorded each year until all trees had begun to bear. As is shown in Table IV, trees on many of the new rootstocks have equalled the performance of those on M.IX and M.II, which are well known for inducing early fruit bud formation in the scion, and it is of interest to relate these figures to tree size as indicated by girth (Table I).

Table IV.

Number of fruit buds per tree, 1947-51.

Rootstock.*	1947–1948.	1949.	1950.	1951.	Total.
3426	24	52	80	97	253
3431	24	41	86	114	265
M.IX	25	77	135	196	433
3436	29	91	246	366	732
M.VII	19	102	326	658	1,105
M.II	38	81	265	446	830
3428	15	81	240	441	777
3438	8	51	298	462	819
M.XVI	2	8	126	353	489
Crab C	2	9	189	390	590
3430	6	65	349	553	973

* Arranged in ascending order for vigour of worked trees (see Table I).

In the very vigorous group, rootstocks 3430 and 3438 have induced fruit bud formation very much earlier than the rootstocks M.XVI and Malling Crab C, which are of comparable vigour. Both these new rootstocks have the same parents, M.IX and M.XII, and the precocious habit of the former parent appears to have been successfully combined with the vigour of the latter.

Table V.

Mean anchorage category per tree, 1953.

(1 = very loose. 2 = loose. 3 = intermediate. 4 = firm. 5 = very firm.)

										Sig. diff. $P<0·05$
Trial A										
	3426	3413	3424	M.IX	**3431**	3419	341	M.VII		
	1·3	1·4	1·5	1·8	2·0	2·3	3·9	4·4		0·5
Trial B										
	3423	3420	3421	3422	**3436**	M.IV	M.II	**3428**	M.VII	
	1·2	1·4	1·8	2·0	2·5	2·9	3·5	3·9	4·0	0·5
Trial C										
	3435	3437	3432	M.II	3414	**3430**	Crab C	**3438**	M.XVI	
	1·1	1·7	1·8	2·9	3·3	4·8	4·9	4·9	5·0	0·5

Anchorage.

During the winter of 1952 when the trees were seven years old an anchorage record was made for all trees. They were untied and their resistance to rocking by hand assessed in five categories by two recorders working independently. The data were analysed and the mean category figures are summarized in Table V, the higher figures indicating better anchorage. Trees on most of the very dwarfing rootstocks were no better anchored than those on M.IX, but trees on 3419, which are similar in size to those on M.IX, were better anchored.

Fruit yield.

Fruit yield is summarized in Table VI. In Trial C, trees on the very vigorous rootstocks 3430 and 3438, although similar in inducing precocity in fruit bud formation, behaved differently in cropping. While trees on 3430 yielded a significantly heavier total crop than those on M.XVI they compare unfavourably with the crop from trees on Malling Crab C.

TABLE VI.

TOTAL FRUIT YIELD PER TREE (LB.), 1948-52.

										Sig. diff. P<0·05
Trial A	3424	**3431**	3426	3413	3419	M.IX	341	M.VII		
	15·8	22·9	23·7	31·4	38·9	47·4	60·6	87·2		*15·1*
Trial B	3421	3423	3420	3422	**3436**	M.VII	M.II	M.IV	**3428**	
	26·8	31·6	32·8	42·6	67·9	74·5	82·6	84·5	86·9	*16·4*
Trial C	M.XVI	3435	**3430**	3437	3432	**3438**	M.II	Crab C	3414	
	41·0	47·4	55·3	61·3	66·1	69·5	75·6	80·1	82·7	*14·2*

For trees on these four very vigorous rootstocks an estimate of fruit set was made by expressing the total number of apples harvested as a percentage of the total number of fruit buds formed, thus :

	3430	3438	M.XVI	Crab C
Estimated percentage fruit set to 1952 inclusive ..	12	17	19	23

These figures show that trees on rootstocks 3430 and 3438 set a smaller percentage of their more numerous blossoms than did those on M.XVI and Crab C. The tardy cropping of trees on M.XII in England was reported by Hatton (1935) and, although there are no trees on this rootstock in these trials for direct comparison, it appears that the influence of the M.XII parent in this respect has been greater in rootstock 3430 than in rootstock 3438 and, furthermore, that it has operated independently of the M.IX parent, which appears to have transmitted the character of early fruit bud formation to both rootstocks.

The total crop per unit area of trunk cross-section affords a useful measure of the relative cropping capacity of trees on different rootstocks (Table VII). Many of the very dwarfing rootstocks, 3426 especially, have made trees that are very efficient producers of fruit for their size ; trees on 3431, although significantly smaller than those on M.IX (Table I), are as efficient, on this basis, as trees on the latter rootstock. Similarly, trees on 3436, although smaller than those on M.VII, have cropped as heavily. In the very vigorous group (Trial C) rootstock 3438 seems promising as an improvement over M.XVI for whereas trees on both rootstocks are similar in size those on 3438 have yielded a significantly greater crop.

TABLE VII.

TOTAL CROP, 1948-52, PER UNIT AREA OF TRUNK CROSS-SECTION*.

Trial A								
341	M.VII	3424	M.IX	**3431**	3419	3413	3426	
8·5	9·9	11·0	13·5	14·0	16·3	19·3	25·5	
Trial B								
M.IV	**3428**	M.VII	M.II	3422	**3436**	3421	3423	3420
6·8	7·8	8·0	8·4	9·5	9·8	12·7	13·0	14·5
Trial C								
3430	M.XVI	Crab C	**3438**	M.II	3414	3437	3432	3435
3·5	3·6	5·4	5·5	8·2	9·6	10·3	12·1	14·1

* $\frac{\text{Mean number of apples per tree, 1948–52}}{\text{Mean trunk cross-section per tree (sq. cm.), 1952.}}$

Discussion.

The degree of suckering of many rootstocks in this new series renders them unsuitable for orchard work. If, however, a tolerance of 12 per cent is allowed for the proportion of trees suckering on any one rootstock, a figure that is less than for trees on M.IX, M.VII, and M.IV (Table I), five new rootstocks show promise as possible improvements upon, or additions to, existing ones.

In the dwarfing group, 3431 is outstanding in so far as trees on it have not suckered and this rootstock proves to be the exception to the general trend of an increase in suckering being coupled with a decrease in induced vigour (Table I). The behaviour of this rootstock also strengthens the view that the initial testing of new rootstocks in the nursery for their ability to produce many shoots per stool does not necessarily lead to the selection of rootstocks prone to suckering (Preston, 1953). Trees on 3431 are smaller than those on M.IX but similarly anchored. Such dwarf trees have possibilities for garden use or for experimental work. Furthermore, trees of Cox's Orange Pippin on this rootstock were less damaged by post-blossom lime-sulphur spray than those on M.IX (Preston, Moore, and Bennett, 1951) which had themselves shown considerable resistance to such damage in previous trials (Moore, 1946).

Trees on 3436 are significantly smaller than those on M.VII but they have cropped as heavily ; the main weakness of trees on 3436 is their anchorage, for in this respect they are similar to trees on M.IV but probably better than M.IX. Trees on 3436 are of especial interest as they bridge the gap in tree size between those on the dwarfing M.IX and those on the intermediate M.VII. This rootstock may well have considerable value for producing small trees of manageable size for intensive experiments such as spray trials, etc.

The production of a dwarfing rootstock capable of making a securely anchored tree appears difficult, for rootstocks which have a high percentage of bark in the roots, characteristic of the dwarfing habit (Beakbane and Thompson, 1947), generally possess brittle roots with poor anchorage.

Trees on 3428 are similar in size, anchorage and cropping to those on M.II. This rootstock has made good trees which have responded well to the light method of pruning that has been practised. There is, however, no evidence at present that trees on 3428 are better than those on M.II.

It is too early, at seven years of age, to assess fully the potentialities of trees on rootstocks in the very vigorous group ; nevertheless, trees on 3438 already show distinct improvements in early fruit bud formation and fruit yield over those on M.XVI which are of similar size. The cropping performance of trees on 3438 has been very close to that of trees on the very vigorous Malling Crab C, but the former rootstock is far more readily propagated by the stooling method (Garner, unpublished data). Allowing for tree size the fruit yield from trees on 3430 is much the same as that from trees on M.XVI (Table VII), and not better as might be expected from its relative precocity in fruit bud formation (Table IV). Comparing trees on 3438 and 3430 with those on M.XVI (Tables IV, VI, and VII) it appears that even under conditions of very light pruning, which have brought trees on the very vigorous M.XVI into relatively early bearing, the M.IX parent may have combined early fruit bud formation and, in the case of 3438, early cropping with vigour in a vigour group where this is quite unusual. Further work with trees on 3430 is necessary before its value as a rootstock can be decided.

Further experience is required before the possible commercial importance of any of these rootstocks can be adequately assessed. Meantime, it is considered that 3431, 3436, 3428, 3438 and 3430 alone justify further study, save for the special case of 3426 which has considerable scientific interest as the most dwarfing apple rootstock yet known. These rootstocks have not been released for distribution in the United Kingdom or overseas.

Fig. 1 should be of the greatest interest to the pure botanist as well as to the pomologist, illustrating as it does a far wider degree of control by the rootstock of tree size and vigour even than was already obtainable with the original Malling rootstocks.

Summary.

First results are presented of field trials of a series of new apple rootstocks, the M.IX Crosses, bred at East Malling by crossing M.IX with certain other Malling rootstocks.

Data are presented for rootstock effect upon vigour, suckering propensity, fruit bud formation, anchorage, fruit yield, and crop per unit area of trunk cross-section. Comparable trees on Malling rootstocks afforded standards for comparison.

Trees on the very dwarfing rootstocks suckered more severely than those on more vigorous ones but one dwarfing rootstock proved an important exception.

The behaviour of five new rootstocks, as possibly of promise, is discussed in detail and in relation to existing rootstocks.

Acknowledgements.

These studies were initiated by Sir Ronald G. Hatton. The author gratefully acknowledges the help of the many colleagues who have been concerned in the production and testing of these rootstocks before they reached the field trials, and of the Statistical Section.

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RECENT PROGRESS IN RASPBERRY BREEDING

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Raspberry breeding has been in progress at East Malling Research Station since 1920. A previous report (Grubb, 1935) described the earlier work, and references have subsequently appeared from time to time in the Annual Reports of the Station. Six new varieties have been named and introduced ; their descriptions have been published (Grubb, 1946, 1950 ; Grubb and Harris, 1947 ; Painter, 1948 ; Wood, 1952) and reports have appeared of their performance in Scotland (Wood and Boase, 1952) and in the National Fruit Trials (Potter, 1948, 1951). This report deals chiefly with two of these named varieties and four unnamed selections of the same parentage. Preliminary notes are also given on six selections from more recent families.

Field trials.

Of the four performance trials now reported, three are at East Malling and one at Kirriemuir, Angus. The crop records cover seven years for one trial (A) at East Malling, five years for the others there (B and C), and four years for the Kirriemuir trial (D).

Trial A contains twelve varieties, of which six (Malling Promise, Malling Exploit and Seedlings V, W, Y and Z) were selected from Family 51.† The other six are Norfolk Giant, Newburgh, and four earlier Malling selections. The Kirriemuir trial (D) contains the same six selections of Family 51 and the healthy New Zealand stock of Lloyd George. The eight varieties in Trial B consist of three other selections of Family 51, three from earlier families (including Malling Enterprise and Seedling T), and Norfolk Giant and Malling Promise as standards of comparison. Trial C includes Malling Promise, Malling Exploit, and two stocks of Lloyd George (the New Zealand and former ' Amos ' stocks).

The emphasis in this report is on the behaviour of the selections of Family 51, compared with Norfolk Giant at East Malling, and New Zealand Lloyd George at East Malling and Kirriemuir. Of the six more recent selections discussed, three are from Family 64, two from Family 69, and one from Family 72.

TABLE I.

Trial A.—Yields in cwt. per acre.

	1947	1948	1949	1950	1951	1952	1953	Average.
Seedling T	9·5	53·7	47·8	66·7	112·9	106·0	96·9	70·4
Seedling W	15·9	83·1	72·1	61·0	81·5	92·3	79·3	69·3
Seedling Y	13·1	88·3	78·6	57·9	81·8	91·4	65·0	68·0
Malling Promise	6·3	68·4	70·5	50·8	73·3	115·2	64·4	64·1
Malling Exploit	9·1	55·6	88·2	42·0	66·7	107·1	50·5	59·9
Seedling Z	6·5	61·9	57·1	39·7	62·2	93·8	70·7	56·0
Norfolk Giant	6·5	45·8	46·5	45·4	73·9	79·2	67·4	52·1
Seedling V	6·5	59·6	61·2	40·4	62·2	74·7	59·4	52·0
Newburgh	6·2	42·6	54·4	34·1	68·9	67·2	49·7	46·2
Significant difference (P=0·05)								*6·42*

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† Genealogies of Families 51, 64, 69 and 72 are given in Appendix 1, and a list of families in Appendix 2.

Trials A and B, planted in the winters of 1945-46 and 1947-48 respectively, are of randomized block design with six replicates. The rows are six feet apart and the plants two feet apart in the row, and each unit plot consists of 21 consecutive plants (i.e. a length of row occupying about 1/173 of an acre). Table I shows the cropping of nine of the varieties. (The others, Seedlings H (32/180), S (32/155), and U (37/1), are being discarded, chiefly owing to virus susceptibility.) In this and subsequent tables averages which do not differ significantly are joined by brackets.

Table II shows similar data for seven of the varieties in Trial B, one again being discarded for its virus susceptibility.

TABLE II.

Trial B.—Yields in cwt. per acre.

	1949	1950	1951	1952	1953	Average.
Seedling 51/47	29·1	54·5	94·9	105·8	75·6	72·0
Seedling T	10·2	39·5	97·3	96·2	83·7	65·4
Malling Promise	22·0	48·8	79·4	98·2	54·1	60·5
Norfolk Giant	15·8	43·2	75·8	72·5	53·2	52·1
Malling Enterprise	16·5	31·3	72·8	75·2	58·1	50·8
Seedling 51/35	17·0	24·6	76·1	76·0	53·2	49·4
Seedling 51/23	19·1	27·0	75·0	70·2	46·6	47·6
Significant difference (P=0·05)						*4·18*

In Trial C, planted in winter of 1947-48, data for which are given in Table III, the unit plot remains the same but there are only three replicates of each variety.

TABLE III.

Trial C.—Yields in cwt. per acre.

	1949	1950	1951	1952	1953	Average.
Lloyd George (New Zealand)	24·9	47·4	68·5	94·0	88·9	64·7
Malling Promise	19·2	38·7	67·3	83·9	63·9	54·6
Lloyd George (' Amos ')	19·7	37·1	62·6	83·2	67·2	54·0
Malling Exploit	25·2	38·2	63·3	84·5	48·6	52·0
Significant difference (P=0·05)						*8·86*

Kirriemuir.

Trial D is also of randomized block design, with six replicates of each of the main varieties and single observational plots of the six selections from Families 64, 69, and 72. It was planted in February 1949, as part of a large commercial plantation, in which the rows are $5\frac{3}{4}$ feet apart and the plants 3 feet apart in the rows. The unit plot in the trial consists of 18 consecutive plants, or about 1/140 of an acre. Table IV shows the cropping of the main varieties.

TABLE IV.

Trial D.—Yields in cwt. per acre.

	1950	1951	1952	1953	Average.
Malling Exploit	31·4	126·8	124·9	67·4	87·6
Lloyd George (New Zealand)	49·6	110·2	91·8	57·6	77·3
Seedling W	35·6	94·3	92·1	65·2	71·8
Malling Promise	42·4	85·1	98·5	52·7	69·7
Seedling Z	17·7	91·8	90·9	63·2	65·9
Seedling Y	25·2	108·2	78·0	52·1	65·8
Seedling V	19·4	74·0	89·3	67·2	62·5
		Significant difference ($P=0\cdot05$)			*6·0*

Discussion of results.

The data given show several features of interest. Those varieties which occur in more than one of the East Malling trials have cropped in the same order in each, but whereas Malling Promise has slightly outyielded Malling Exploit at East Malling, the reverse has happened markedly at Kirriemuir. Exploit has also been the outstanding variety in the National Fruit Trials at Wisley in recent years (Potter, 1951). Both varieties have given significantly greater yields than Norfolk Giant at East Malling, but have been themselves outyielded in Trial C by the New Zealand stock of Lloyd George. At Kirriemuir, however, Malling Exploit has held first place in three of four somewhat contrasting seasons, its average annual crop being significantly greater than that of New Zealand Lloyd George. Incidentally, Trial C, to the writers' knowledge, affords the only recorded comparison between the New Zealand stock of Lloyd George and the vigorous but somewhat virus infected ' Amos ' stock which it has replaced in commerce.

In 1950, crops at East Malling were relatively poor. In 1951 and 1952, however, yields were much heavier, the increase coinciding with the use of more generous annual dressings of dung. It seems possible that the manuring may have affected the varieties unequally, and that this may explain the high average yield of Seedling T, which is due largely to its cropping from 1951 to 1953. On the other hand, long observation suggests that this seedling is slow to become established. The general reduction in yields in 1953, both at East Malling and Kirriemuir, was due largely to Grey Mould (*Botrytis cinerea*) of the fruit in a wet season. All varieties were affected, but chiefly those ripening early ; Malling Exploit probably suffered most at East Malling, and Exploit and Promise about equally at Kirriemuir.

The overall cropping of these trials, however, has been very satisfactory. When the East Malling raspberry work began, a crop of 2 tons per acre was considered good, and the senior writer well recalls the feeling of pleasure when Lloyd George and Red Cross first reached 3 tons. In Trial A, disregarding the first light crop of 1947, the average yield of the nine varieties has only once (1950) fallen below 3 tons, and in 1952 exceeded 4½ tons. The heaviest individual crops at East Malling have been those of Malling Promise (Trial A) in 1952, of 5¾ tons per acre, and of Seedling T in 1951, of over 5½ tons ; whilst at Kirriemuir, crops of over 5½ and 6¼ tons have been yielded by New Zealand Lloyd George and Malling Exploit respectively. With potential production raised to such levels, selection by the breeder is increasingly determined by considerations of such factors as growth, habit, freedom from disease, size, appearance, firmness of texture, the edible quality of the fruit, and its suitability for processing.

BREEDING

Origins of the Malling varieties in the trials.

Most of the seedlings discussed in this report were selected from Families 51, 64, 69, and 72. The genealogies in Appendix 1 trace the origins of these from as far back as information is available. Seedling T was selected from an earlier Family, 32.

The seed parent of Family 51, Newburgh, was raised at the New York State Agricultural Experiment Station, Geneva, New York, from a cross of Newman and Herbert. Nothing definite seems to be known of the origins of these varieties, and the former has probably not been grown in Great Britain. Herbert was at one time grown at East Malling, but, although it seemed about the best of the then known American varieties, it appeared to have little value for English conditions.

Newburgh was introduced into Britain in about 1934, and has been grown commercially to some extent both in England and Scotland. At East Malling it at first seemed outstanding, but it has not been a general success in this country. It has proved highly susceptible to the Raspberry Cane Midge (*Thomasiniana theobaldi* Barnes) and associated fungal infections (Pitcher, 1948 and 1951), and the fruit is frequently too crumbly in texture. In areas and seasons where these troubles are avoided, however, it remains a remarkably fine variety, chiefly for the large size, bright colour, firmness, and good edible quality of the fruit, and the general good growth of the plants. Although all stocks of Newburgh appear to be infected with certain mosaic viruses, the plants are vigorous and seldom show symptoms of infection in the foliage. The canes are erect, fairly stiff, and not unduly thorny.

The pollen parent of Family 51, Seedling 30/8, was derived by in-breeding from Pyne's Royal and Lloyd George, and, although useless commercially (like nearly all ' selfs '), is in some respects the best parent variety so far used at East Malling. It was chosen for breeding mainly for the very large size of its fruit, which is well maintained to the end of the season. It has proved to have certain further advantages, though coupled with some faults which are mentioned later.

Families 64 and 69 each include in their earlier parentages the variety Preussen, and Family 64 includes also Baumforth's Seedling A ; both these varieties are still found occasionally in cultivation. Preussen is a raspberry of good fruit colour and very good flavour, but of soft texture and only moderate cropping capacity. Baumforth's Seedling A, once widely grown, was a high-yielding variety with soft, juicy, acid-flavoured fruit. These and other varieties used as breeding material are described in more detail elsewhere (Grubb, 1922 ; Wood, 1952).

Family 72 was derived directly from Family 51, and Family 32 from the cross Preussen × Lloyd George.

Characteristics of Family 51 and their probable origin.

Plants are mostly vigorous or very vigorous, and usually produce a great many canes (' spawn '), especially in their second year ; a few plants were of only moderate vigour, but none noticeably weak. Vigour is common, but not universal, in families raised by crossing varieties of unlike origin ; but profuse ' spawn ' production is by no means always characteristic of such crosses, even where cane growth is very tall. In this family this character is probably derived from both parents, but especially from Newburgh.

Cane habit varies from almost erect to widely spreading, a few seedlings being almost as spreading as Norfolk Giant. The canes are often fairly stiff, but sometimes much the reverse ; none are as stiffly erect as Malling Jewel or Newburgh. The spreading habit and lack of stiffness, where present, are probably derived mainly from Seedling 30/8.

Cane colour varies from green (becoming brown) to bright or dark red nearly all over ; but few are as red as Newburgh. The green colour is almost certainly derived from Seedling 30/8.

Spines are very variable in colour. Sometimes they are all dark and sometimes all ' tinged ', but more often they are mixed like those of Newburgh. Most seedlings have larger and more numerous spines than Newburgh. The canes are all glabrous or nearly so.

Leaves nearly always closely resemble those of Newburgh, although the leaflets vary from the wide type seen in Malling Promise to the narrow, pointed type of 51/47. The ' family characteristic ' of the foliage is sufficiently pronounced to make it difficult to separate mixtures of the main selections.

Fruit yields, as shown by the Tables, are very variable, but often heavy. Records exist for nine selections and for Newburgh, but none for 30/8. Although in Trial A the crop from Newburgh was comparatively low, the heavy cropping of several selections may be derived as much, or more, from Newburgh as from 30/8.

Time of ripening varied considerably, but most of the heavy-cropping selections are early or second-early ; Seedling W is the chief exception. The time of ripening of 30/8 is not well known, but is certainly fairly early. Since Newburgh is midseason or later, and Family 50 (Malling Jewel × Newburgh) consisted mainly of midseason and later varieties (including the very late Seedling 50/15), the earliness of Malling Promise, Malling Exploit, and Seedlings Y, Z, and 51/47 is almost certainly derived from 30/8.

Fruit size. In this the family was again very variable. In the majority of seedlings the fruits were of medium size or larger, but several were outstandingly large. A few had small, crumbly fruit. There is little doubt that the great size of some was derived mainly from 30/8. Very large fruits have since appeared in Families 61 (Norfolk Giant × 30/8) and 64 (Malling Landmark × 30/8), whereas in Family 50 (Malling Jewel × Newburgh) none were particularly large.

Fruit colour was also rather variable. Most of the surviving selections are barely satisfactory, and few really brightly coloured. Bright colour, where present, is probably derived mainly from Newburgh.

Flavour is a more elusive character. Several selections are generally well liked, and in the senior writer's opinion none were disagreeable as were some of the early East Malling seedlings derived from Bath's Perfection and Pyne's Royal. It seems likely that good flavour, where present, is derived from both parents.

Fruit firmness was by no means general, although both parents have reasonably firm fruit. This, too, is a rather elusive character ; extremes are easily recognized, but intermediate forms seem to vary from year to year and in different soils. Newburgh probably tends to produce forms with firm fruit, and 30/8, when selfed, has given a variable family (80) in which a few seedlings have fruit of outstanding firmness. This occurs again in Family 64 (Malling Landmark × 30/8), in which the parent Landmark is probably nearly homozygous for soft fruit. Firmness in Family 51 is, therefore, probably derived from both parents.

Large drupelets, usually associated with crumbly texture of the fruit, were evident in many members of the family, and several were discarded for this reason alone. Since nearly every plant of Family 48 (Newburgh selfed) showed this fault to an extreme, and very few did so in Family 80 (30/8 selfed), it probably originates mainly from Newburgh.

Ease of 'plugging' was not universal. Although neither parent plugs badly, difficult plugging occurred in some 16 per cent of the seedlings. Judging by other families of which 30/8 was a parent, the fault is derived mainly from Newburgh.

Lax fruit trusses, which hang down and hide much of the fruit behind the foliage, are characteristic of certain selections, though not of all. This fault is probably derived mainly from 30/8.

Susceptibility of the fruit to Botrytis rot, which affected some varieties much more than others in 1953, seems likely to be correlated mainly with time of ripening, though possibly to some extent with soft texture. Serious outbreaks occur so rarely that it may be several years before further observations can be made, and then a different range of varieties may be affected, according to the time when critical weather conditions occur.

Virus relationships. Most plants of Family 51 seem to resemble Newburgh more than 30/8. Several selections appear slow to become infected with mosaic viruses under field conditions, and the majority are probably fairly tolerant of infection. These characteristics occur in Newburgh, but probably not in 30/8.

Notes on individual selections from Families 51 and 32.

Malling Promise (*51/79*) was the first of the Malling raspberries to be named. When it was released, commercial varieties of this standard were so scarce, and the variety itself could be propagated so rapidly, that it was over-planted. Experience has shown it to be adaptable to a wide range of growing conditions, but not to all uses. Although very good for local retail trade, the fruit is not ideal for long distance transport or for canning or quick-freezing ; and whilst the bulk still goes to the jam market, it appears that jam manufacturers are not fully satisfied with it either. The widespread incidence of Botrytis rot in 1953 affected Promise as much as most early varieties, and, although such outbreaks are rare, many growers are now chary of planting the variety. With good alternatives now available, Malling Promise will perhaps assume a more proper place in the industry, namely as an early contributor to the jam market and a variety for retail sale and garden use. Even for the latter purposes it is at present surpassed by Malling Exploit ; although in the writers' opinion there is still a possibility that Exploit, as a variety, may have a shorter useful life than Promise.

The cropping capacity of Malling Promise is fairly well shown by the present trials. Although it usually outyields Malling Jewel (Wood and Boase, 1952), it is less consistent than that variety and has in several places given a smaller crop than Exploit. Nor is it always satisfactory to pick, for although the fruit is seldom 'tight on the plug', in certain conditions the pedicel becomes brittle and breaks readily, leaving the plug in the berry. For this reason, and because their fruit is more conspicuous, pickers prefer Malling Jewel or Seedling T. The fruits of Promise often ripen unevenly, the tip remaining green after the rest of the fruit has coloured ; and the texture is sometimes barely firm enough for the fresh fruit market.

Malling Promise appears slow to become infected with mosaic viruses, and little injured when infected. It is sometimes rather susceptible to the Raspberry Cane Midge and associated infections, though less so than Newburgh. It has been self-pollinated to produce Family 72, and crossed, as pollen parent, with Malling Landmark to produce Family 65. As a parent, it may prove at least as useful as Landmark.

Malling Exploit (*51/84*) (formerly *Seedling X*) often surpasses Promise in vigour of growth, cropping, and in the size, colour, dessert quality, and perhaps firmness of the fruit. The canes are less erect in habit, and being usually taller, sometimes have more tendency to block the alleyways in autumn ; but this fault is seldom as pronounced as in Norfolk Giant.

Like Promise, Exploit ripens as a first early. In the East Malling trials it has been slightly later than Promise in the first year or two of cropping, and has then become slightly the earlier ; whilst at Kirriemuir it has been always slightly the later. The fruit, though ripening more evenly than that of Promise, has larger drupelets and may tend to become crumbly as the plants get older.

Exploit appears to be one of the best varieties at present available for retail sale. It is no better liked than Promise for canning, but has been reported good for quick freezing. Its suitability for jam-making has not yet been properly assessed. It appears to resemble Promise in its relationship to the mosaic viruses and to the Raspberry Cane Midge, and in 1953 suffered as badly as Promise from Botrytis rot. It has been self-pollinated to produce Family 107, and crossed, as pollen parent, with Boysenberry to produce Families 93 and 102 ; but its value as a parent cannot yet be assessed.

Seedling V (*51/4*) resembles Promise in habit of growth and vigour, but ripens in midseason or later. In the present trials it has been considerably lighter in cropping. In the nursery, the canes have the disadvantage of retaining their foliage very late into the autumn, even later than those of Lloyd George.

At its best, the fruit is superior in smoothness of shape and general attractiveness of appearance to that of either Promise or Exploit, and the small drupelets indicate that it is unlikely to become crumbly. Present reports on its canning and quick-freezing quality are favourable, but little is known of its jamming quality. Tests have shown that stocks are often infected with one or more mosaic viruses, but with little apparent injury, and the variety has not shown marked susceptibility to Raspberry Cane Midge.

Reports on Seedling V from the south-west of England, particularly from Devonshire, have been favourable. There it appears to crop fairly heavily and consistently. There is a need for a late variety of better quality and appearance than Norfolk Giant.

Seedling W (*51/57*) is about the most stiffly erect in habit of all the selections from Family 51, and in cropping has frequently equalled, and sometimes exceeded, Promise and Exploit. The fruit, however, is of less attractive appearance, and too small for the variety to be useful commercially. Existing stocks are considerably infected by mosaic viruses, though again without apparent injury. This selection is being discarded.

Seedling Y (*51/85*) is in habit at least as spreading as Exploit, and the canes are less stiff ; the fruiting canes and supporting wires being apt to sag under the weight of the crop. Whilst Seedling Y has at times exceeded both Promise and Exploit in yield, the fruit is smaller and of less attractive shape and colour, and sometimes tends to drop seriously if left too long on the canes. Its season is second-early, and not sufficiently later than that of Promise and Exploit to provide a useful succession. Stocks of this seedling are thought to be generally infected with mosaic viruses, and in some seasons the new canes have proved very susceptible to Botrytis infection in the autumn. This selection is being discarded.

Seedling Z (*51/90*), like Promise and Exploit, ripens as a first early ; in habit it resembles Promise. Since it usually falls below these varieties in yield, and has no special advantages, it is being discarded.

Seedling 51/47 is another high-yielding first-early selection. As one of the later selections from the family, it has not yet been adequately tested, but its performance in Trial B (Table II) has been outstanding. In cane habit it is intermediate between Promise and Exploit, but it has longer internodes and a lighter, less dense foliage ; consequently the fruit is more conspicuous. In attractiveness of appearance the fruit is considered about equal to that of Promise, and it ripens more evenly. Its value for processing is not yet known.

Its virus status is not yet known, but existing stocks are vigorous. It has shown no marked susceptibility to Raspberry Cane Midge.

Seedling T (*32/41*) is one of the last selections from Family 32, which also produced Malling Notable and Seedlings G and M. Though apparently slow to establish itself, it has certain advantages which may justify its further trial.

The canes are almost as stiffly erect as those of Malling Jewel. The fruit, like that of Jewel and Seedling M, is little hidden by foliage and remarkably easy to pick. Its value for processing is not yet known : it may be hardly firm enough except for jam, and for retail sale is unlikely to rival either Promise or Exploit. Its cropping in Trials A and B (Tables I and II), however, has been excellent, chiefly since the change in manuring already mentioned.

Stocks are probably much infected with mosaic viruses. Occasional plants show distinct symptoms, and are usually reduced in vigour. It has shown little susceptibility to Raspberry Cane Midge.

Selections from more recent families.

Of twelve families germinated in 1945, three (64, 69, and 72) made better growth than the remainder and fruited quite well in 1946. From these some 84 selections were made, and available canes divided between East Malling and three sites in Scotland. After observations at these centres from 1947 to 1949, six seedlings were selected as being the most generally promising, and single plots of each were included in Trial D. They have since been planted in a replicated trial at the Scottish Horticultural Research Institute, together with six named varieties.

Characteristics of Family 64.

This family, from the cross Malling Landmark × 30/8, seemed for a time much more promising than either 69 or 72. Most plants were vigorous, and many reasonably erect ; while many had very large fruit, some of highly attractive appearance. It appeared, however, to have inherited several of the faults of Landmark. The canes in many cases are excessively thorny, and the fruits of many, including several of the finest appearance, are too soft. Others were rejected for bad plugging. Ultimately three seedlings were selected, but, while in many ways excellent, they are far from faultless.

Landmark is a parent of three other families : 65 (Landmark × Promise), 68 (Seedling 48/6 × Landmark) and 71 (Landmark selfed). It certainly seems to transmit the faults of thorny canes, soft fruit, and poor plugging. On the other hand, it may transmit resistance to mosaic infection, and this, if confirmed, will perhaps justify its use in breeding.

Characteristics of Family 69.

This cross of a second-generation self from the cross of Preussen and Lloyd George (59/30) with a self of Newburgh (48/8) was expected to yield a fairly uniform family. Early observations suggested that it was uniform in mediocrity ; but longer experience has revealed more variation than at first appeared, and certain good qualities that may eventually make this family more useful than 64.

The plants have nearly all been vigorous, with canes mostly erect and fairly stiff and with a characteristic foliage as easy to recognize as that of Family 51. Most were midseason or later in ripening, and many had reasonably bright-coloured fruits of large, but not outstanding, size. Fewer than might have been expected had the large drupelets characteristic of most selfs of Newburgh, and few were difficult to plug. The majority had fruit firm enough for most purposes, and the two surviving selections have since been found suitable for canning.

A characteristic of nearly all seedlings of Family 69 is the habit of flowering on the tips of the new canes, but usually much too late in the year for the fruit to ripen. Since Newburgh and its ' selfs ' have this habit as little as any known varieties, it is probably derived directly from Seedling 59/30, and originally from Lloyd George.

Characteristics of Family 72.

This family, raised by self-pollinating Malling Promise, showed better vigour than many other in-bred families, the vigour of a few selections being quite remarkable. Cane production also was apparently unimpaired, nearly all the propagated seedlings being as prolific in spawn in their second year as Promise. In addition nearly all resembled Promise in habit. Many had large fruits, some outstandingly large, and several showed the uneven ripening of Promise. Apart from those lacking sufficient vigour, several were rejected either for bad plugging, large drupelets, or dull-coloured (though seldom dark) fruit. One selection remains on trial.

Notes on individual seedlings and their progeny.

Seedling 64/2 now seems unlikely to justify early hopes. The fruit is exceptionally large, but is not always firm enough, especially when fully ripe, and sometimes not easy to plug. The plants have a distinctly spreading habit, at least when young, the canes are rather too thorny, and the fruiting laterals much too long and lax. The colour of the fruit is a little, but perhaps not too dull. Ripening is about midseason.

Seedling 64/53, in the senior writer's opinion, has the most attractive looking fruit of all the seedlings hitherto raised at East Malling. When first seen it was marked as outstanding. Though not of the largest size, the fruit is large enough, and the texture so far has been firm. The small, closely-set drupelets give a smooth, oval shape, and the colour is reasonably bright, not darkening noticeably even when fully ripe. In flavour it seems one of the best, and no difficulty in plugging has yet been noticed. The canes are tall enough, erect, stiff, and not seriously thorny. Its one fault is that on some soils, at least, it produces too few canes. Experience alone will show how serious this is : the few records at present available suggest that the variety crops well in spite of it. The fruit is probably midseason or later in ripening.

This seedling has not yet been used as a parent of red raspberries, but was crossed, as pollen parent, with Cumberland black raspberry (*Rubus occidentalis*) to produce the hybrid Family 75, germinated in 1948. A further family (84), germinated in 1950, was produced by a similar cross of Cumberland with Seedling 30/8. These families have close resemblances, but differ in that several seedlings of Family 84 show symptoms of mosaic infection more readily in the field than do those of Family 75. This, if confirmed to be due to resistance to infection on the part of Family 75, must be derived from the Landmark parentage of 64/53, and can thus be traced to Baumforth's Seedling A, the pollen parent of Landmark, which was long recognized as a healthy variety, with a long life. It is possible, therefore, that Seedling 64/53 will prove useful as a parent imparting resistance to mosaic infection.

Seedling 64/64 seems in many respects similar to Seedling 64/2, but the canes are less spreading and thorny and the fruiting laterals rather more stiffly held. Its vigour and cane production in Scotland have been variable, but generally disappointing. The fruit, though very large, is not equal to that of 64/2, and may also be a little darker in colour when fully ripe. It seems a little later in season than 64/2.

Family 81, raised by self-pollinating 64/64, promises little either in itself or for breeding. Whilst the loss of vigour is less than in many in-bred families, nearly all the seedlings have very dull-coloured fruit. Most are midseason or late in ripening.

Seedling 69/105 has certain clear advantages, and may prove to be the most useful of these six selections. The canes are tall enough, erect, stiff, and fairly numerous—sometimes too many when the plants are young—and the fruiting laterals are of medium length and well held out. The fruit, though not of the very largest, is of good size and probably the brightest in colour of the six. It is firm, easy to plug, and smoothly oval in shape, with small, closely-set drupelets. Its general appearance is attractive, but its flavour is only fair. It is midseason in ripening. Though little is yet known of the cropping capacity of any of these seedlings, 69/105 seems likely to be one of the best, and first reports indicate that it is suitable for canning. It has not yet been used for breeding.

Seedling 69/139 closely resembles 69/105. Its cane production may be slightly higher, and the fruit seems generally larger, though less smooth and attractive in appearance, with slightly larger drupelets and not quite so bright a colour. The flavour is fair only. It is midseason in ripening, being possibly a little before 69/105. First reports indicate that it is suitable for canning. It has not yet been used for breeding.

Seedling 72/59 is one of the two most vigorous ' selfs ' ever propagated at East Malling. (The other, 55/6, has a parentage traceable to Burnetholm Seedling and Preussen.) Such seedlings are, as a rule, too weak to be commercially useful, however good they may otherwise be ; but this and 55/6 appear to be vigorous enough for any purpose.

It produces ample canes, which are erect and fairly stiff. The fruit is conspicuous, usually easy to pick, and at its best one of the very largest, resembling that of Malling Promise but with a more nearly cylindrical shape, and less tendency to ripen unevenly. Its season is first-early, like that of Promise. In the Scottish trials it has on occasion given fruits of exceptional length, some exceeding two inches.

Family 91, germinated in 1952, was raised by crossing 55/6 and 72/59. Both parents being vigorous and, as far as can be known, of widely different ancestry, the resultant family was expected to show extreme vigour. Yet at two years from germination, few plants were as much as six feet high and many only one or two feet. This surprising result may be due to some factor or factors, probably derived from both parents, tending to suppress vigour. Since most of the fruit so far recorded has been large, even where growth has been very weak, this family may be of use in further breeding.

Acknowledgements.

The writers have received much help from many members of the East Malling Staff, both present and past, and from members of the Staff of the Scottish Horticultural Research Institute. They are particularly indebted to the East Malling Statistics Section for the examination of the records of all four trials, and to Mr. G. R. Bruce of Kirriemuir for providing accommodation on his farm for Trial D.

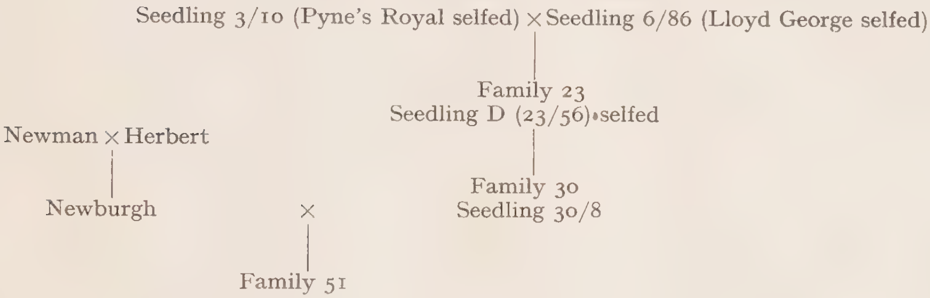
Summary.

Recent progress in raspberry breeding at East Malling is reviewed, and the results given of cropping trials of a number of varieties and seedlings at East Malling and in Scotland. Particulars are given of the families from which the more recent new varieties and seedlings have been raised, together with notes on some of the individual seedlings and their progeny.

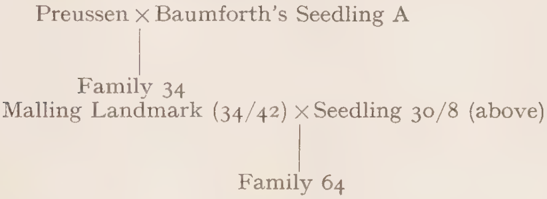
APPENDIX 1

GENEALOGIES

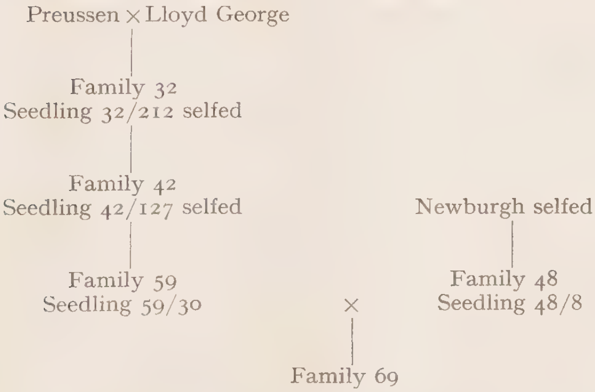
Family 51 (Newburgh × Seedling 30/8*).


Seedling 3/10 (Pyne's Royal selfed) × Seedling 6/86 (Lloyd George selfed)
Family 23
Seedling D (23/56) selfed
Newman × Herbert
Newburgh
×
Family 30
Seedling 30/8
Family 51

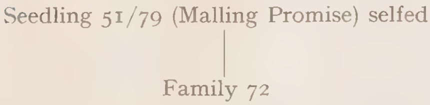
Family 64 (Malling Landmark × Seedling 30/8*).


Preussen × Baumforth's Seedling A
Family 34
Malling Landmark (34/42) × Seedling 30/8 (above)
Family 64

Family 69 (Seedling 59/30 × Seedling 48/8*).


Preussen × Lloyd George
Family 32
Seedling 32/212 selfed
Family 42
Seedling 42/127 selfed
Newburgh selfed
Family 59
Seedling 59/30
×
Family 48
Seedling 48/8
Family 69

Family 72 (Malling Promise selfed).


Seedling 51/79 (Malling Promise) selfed
Family 72

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* The seed (female) parent is given first.

APPENDIX 2

ORIGIN OF FAMILIES

Family No.	Origin.	Selections mentioned.
3	Pyne's Royal selfed	Seedling 3/10, parent of Family 23.
6	Lloyd George selfed	Seedling 6/86, parent of Family 23.
23	Seedling 3/10 × Seedling 6/86	Seedling D (23/56), parent of Family 30.
25	Burnetholm Seedling selfed	Seedling 25/34, parent of Family 37.
30	Seedling D (23/56) selfed	Seedling 30/8, parent of Families 51, 61, 64, 77, 80.
31	Preussen selfed	Seedling 31/56, parent of Family 37.
32	Preussen × Lloyd George	Seedling T (32/41). Seedling 32/212, parent of Family 42.
34	Preussen × Baumforth's Seedling A	Malling Landmark (34/42).
37	Seedling 25/34 × Seedling 31/56	Seedling 37/5, parent of Family 55.
42	Seedling 32/212 selfed	Seedling 42/127, parent of Family 59.
48	Newburgh selfed	Seedlings 48/6, parent of Family 68; 48/8, parent of Family 69.
50	Malling Jewel × Newburgh	Seedling 50/15 (very late).
51	Newburgh × Seedling 30/8	Malling Promise (51/79), Malling Exploit (51/84), etc.
55	Seedling 37/5 selfed	Seedling 55/6, parent of Family 91.
59	Seedling 42/127 selfed	Seedling 59/30, parent of Family 69.
61	Norfolk Giant × Seedling 30/8	
64	Malling Landmark × Seedling 30/8	Seedlings 64/2, 64/53, 64/64.
65	Malling Landmark × Malling Promise	
68	Seedling 48/6 × Malling Landmark	
69	Seedling 59/30 × Seedling 48/8	Seedlings 69/105, 69/139.
71	Malling Landmark selfed	
72	Malling Promise selfed	Seedling 72/59, parent of Family 91.
75	Cumberland (*Rubus occidentalis*) × Seedling 64/53	
80	Seedling 30/8 selfed	
81	Seedling 64/64 selfed	
84	Cumberland × Seedling 30/8	
91	Seedling 55/6 × Seedling 72/59	

Note.—Wherever a selection is mentioned by number, the first number represents the family and the second the number of the plant in the original seedling-bed of that family.

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APPLE PRUNING TRIALS

A PROGRESS REPORT

By A. P. PRESTON

For bush apple trees the pruning methods at present of greatest interest in England are the Established-spur, investigated by Grubb (1932) ; the Renewal, described by Thompson (1941 and 1949) ; and, lightest of all, the Regulated method, also investigated by Grubb (1922). Two tree forms are also commonly used, the open-centre and the delayed open-centre. Few experimental comparisons of these methods have hitherto been made. All methods have, however, been included in trials at East Malling planted in 1945-46. Results for the early establishment period, i.e. the first seven years after planting, for the varieties Cox's Orange Pippin and Worcester Pearmain are described below.

The methods used in developing the primary branch system, together with modifications of these methods resulting from further experience, have been reported previously (Preston, 1949 and 1952). The pruning terms used in this paper are those recommended in a recent report of the Horticultural Education Association (1954).

Material and treatments.

The trials were planted on two widely different soils, the Malling Series of sandy loam texture, and the Lowlands Series of loamy sand texture (Preston and Stanton, 1947 ; Furneaux, 1954). The trees were planted as maidens during the winter of 1945-46 in four trials :

Trial 1 (on Malling Series).

Worcester Pearmain on M.IV at 18×20 ft. Treatments were as follows :

Open-centre, established-spur pruned (OE).
Delayed open-centre, established-spur pruned (DE).
Regulated (Reg.).

One-tree plots of each treatment were distributed within twenty randomized blocks.

Trial 2 (on Lowlands Series).

This trial consisted of the same rootstock/scion combination and treatments as in Trial 1, but the trees were planted 18 ft. square. One-tree plots of each treatment were distributed within sixteen randomized blocks.

Trial 3 (on Malling Series).

Cox's Orange Pippin on M.II at 18×20 ft. Treatments were as follows :

Open-centre, established-spur pruned (OE).
Delayed open-centre, established-spur pruned (DE).
Open-centre, renewal pruned (OR).
Delayed open-centre, renewal pruned (DR).
Regulated (Reg.).

One-tree plots of each treatment were distributed within twelve randomized blocks.

Trial 4 (on Lowlands Series).

This trial consisted of the same rootstock/scion combination as in Trial 3, and the same treatments except that regulated pruning was omitted. The trees were planted 18 ft. square and one-tree plots of each treatment were distributed within six randomized blocks, there being two plots of each treatment within each block.

Shaping and pruning methods.

Open-centre trees.—Trees were headed back to a height of 30 inches on planting and primary branches limited to three. Their leaders were tipped the following winter and a secondary branch framework obtained. Later, other branches were tipped as required to fill in spaces in the tree's framework (Figs. 1 and 2). Any feathers present on the stems were removed.

Delayed open-centre trees.—These were headed back to a height of 33 inches on planting and successive tiers of framework branches formed around a central leader over a period of years. Each primary branch was treated as a single unit and was not allowed to fork. When the trees were seven years old and eight to nine feet high the central leader was cut back into three-year-old wood to a framework branch (Figs. 1 and 2). Any feathers present on the stems were removed.

Established-spur pruning.—Leader tipping became lighter as the tree framework developed. Laterals not required for new branches were classified for vigour ; very vigorous ones were removed completely, some of medium vigour were left uncut to form fruit buds and were shortened back later, very weak ones were cut back to three inches to form induced spurs. Once established-spurs were formed, laterals arising from them were shortened to one inch. With trees of Worcester Pearmain, a number of dards and brindilles with terminal fruit buds were left uncut.

Renewal pruning.—As with established-spur pruning leader tipping became lighter as the tree developed. About one-third of the one-year laterals were shortened each year to two or three inches to provide more the following year, the remainder being left uncut. Approximately half of those left uncut were shortened back the following year, leaving seven or eight fruit buds on each lateral ; the remainder were again left uncut. Many three-year laterals were left in for a further year before they were stubbed to produce more one-year laterals.

Regulated pruning.—Trees were headed back to 30 inches on planting, no attempt being made in this case to restrict the number of primary branches. During each of the ensuing two years not more than three leaders were tipped each year ; leader tipping then ceased. Laterals were neither spur-pruned nor shortened, but crowded, thin, and weak laterals, as well as those that competed with the unpruned leaders, were removed completely, irrespective of age. Any feathers present on the stems were removed.

Results.

Vigour.

Trunk girth was measured annually, nine inches above the union. Data for mean trunk girth seven years from planting showed that delayed open-centre and regulated trees of Worcester Pearmain had, generally speaking, larger girths than open-centre trees in both Trials 1 and 2 (Table I). Trees on the Malling Series were larger than those on Lowlands Series for all treatments, but it was not possible to test this site difference statistically. The effects on trees of Cox's Orange Pippin in Trials 3 and 4 did not differ significantly.

The analyses on trunk girth and new shoot growth data were carried out on their logarithms. Significant differences are transformed into significant ratios when the data are transformed back again.

TABLE I.

MEAN TRUNK GIRTH (CM.) OF WORCESTER PEARMAIN ON M.IV SEVEN YEARS FROM PLANTING.

Trial.	Soil series.	Treatment.			*Sig. ratio* ($P=0\cdot05$).
		OE	DE	Reg.	
1	Malling	20·9	21·4	22·2	*1·04*
2	Lowlands	14·5	15·5	16·4	*1·10*

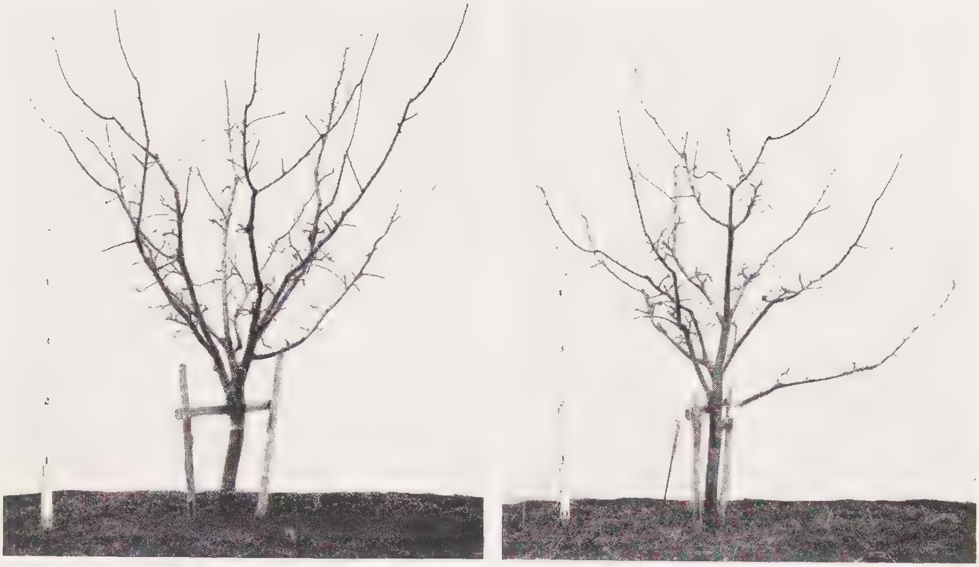
New shoot growth is shown in Table II for the trials on Malling Series ; these were the only ones that showed significant differences between treatments.

In both trials regulated trees made significantly less shoot growth than those under other pruning treatments. With trees of Cox's Orange Pippin in Trial 3 the difference between renewal and established-spur pruning treatments was as follows :

	Renewal.	Established-spur.	
Total shoot growth (m.)	251	297	($P<0\cdot01$)

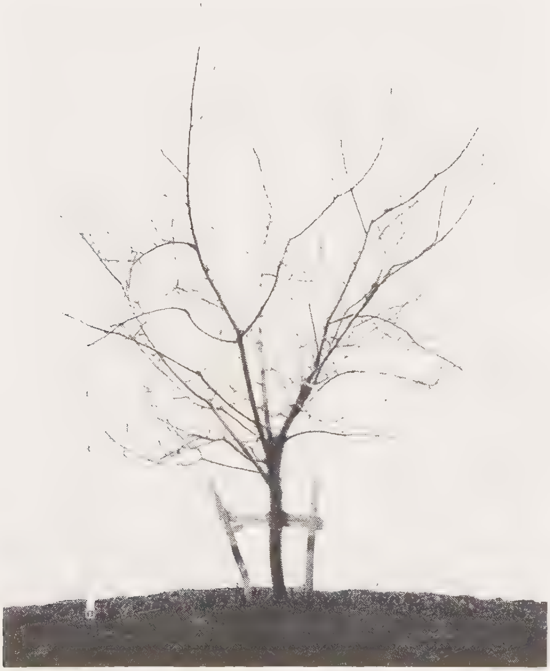
In the same trial delayed open-centre trees made more shoot growth than open-centre ones :

	Open-centre.	Delayed open-centre.	
Total shoot growth (m.)	256	291	($P<0\cdot05$)



Open-centre, established-spur pruned.

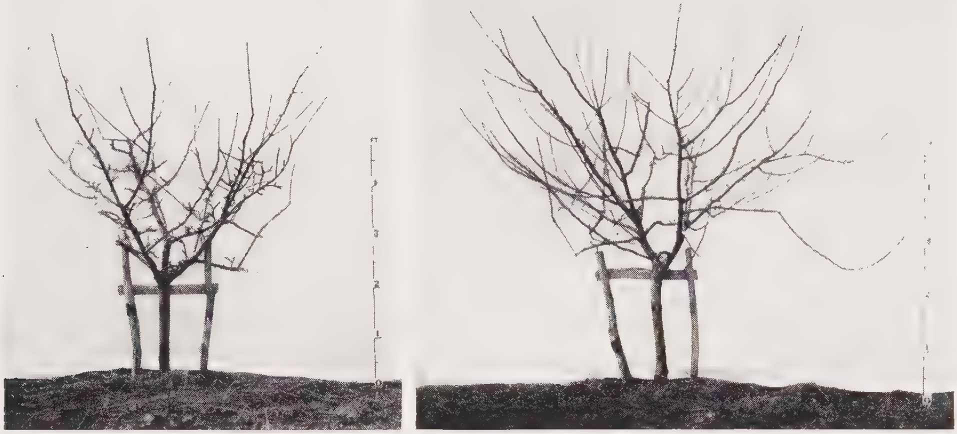
Delayed open-centre, established-spur pruned.



Regulated.

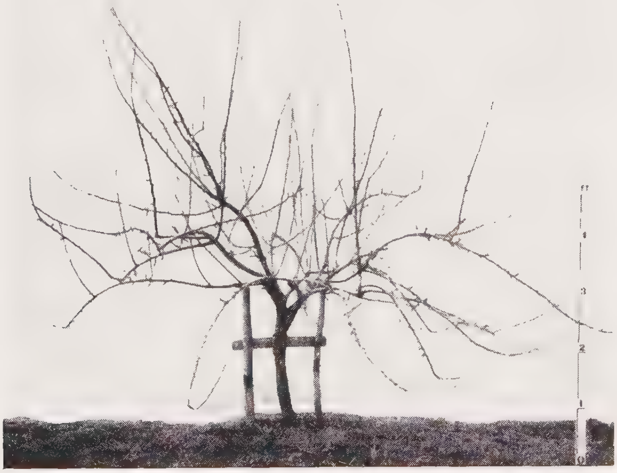
Fig. 1.

Seven-year-old trees of Worcester Pearmain on M.IV after pruning.

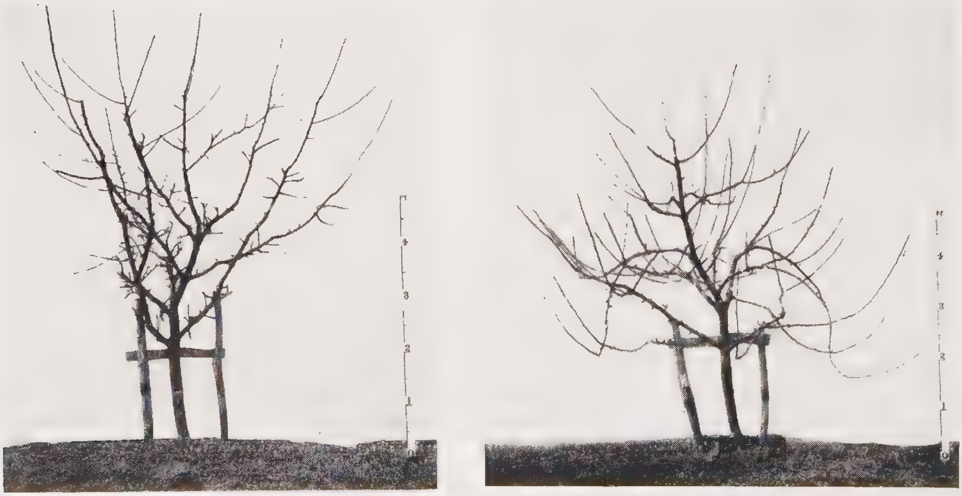


Open-centre, established-spur pruned.

Open-centre, renewal pruned.



Regulated.

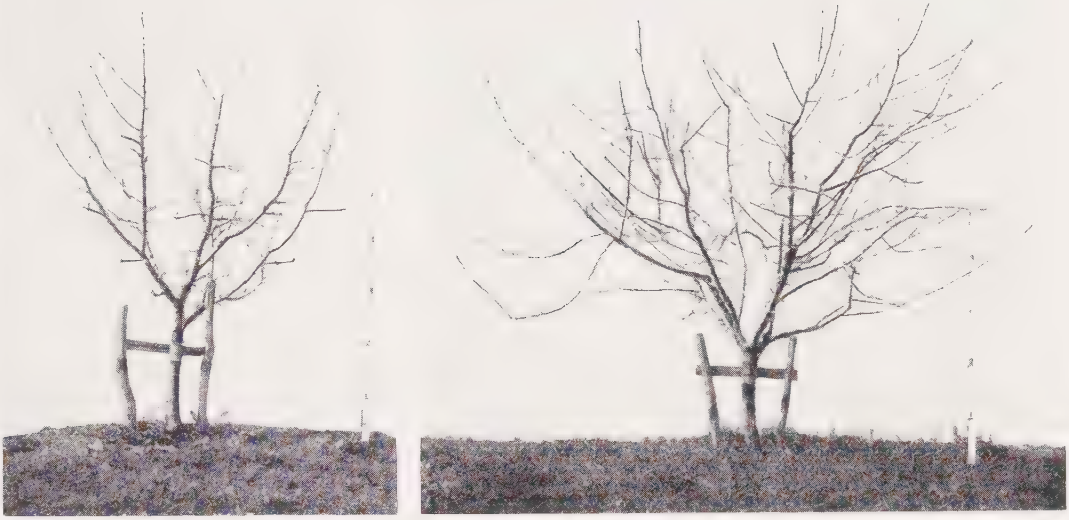


Delayed open-centre, established-spur pruned.

Delayed open-centre, renewal pruned.

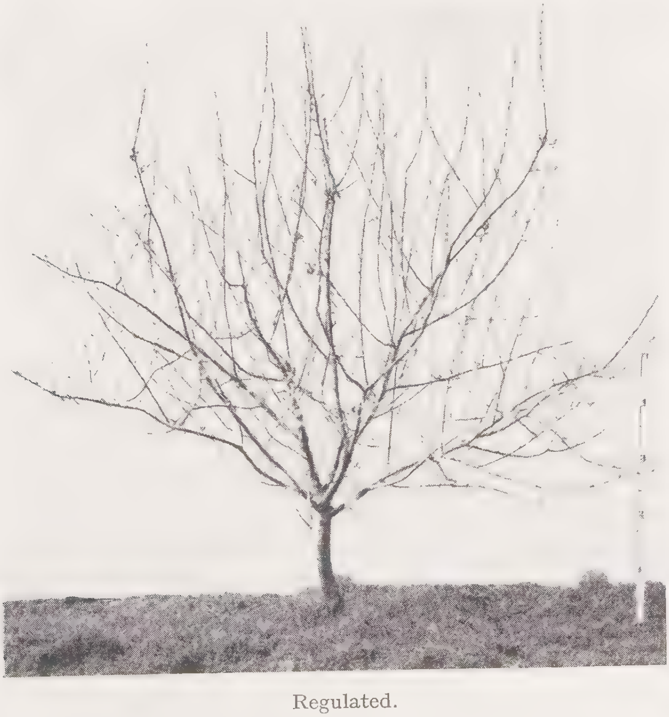
FIG. 2.

Seven-year-old trees of Cox's Orange Pippin on M.II after pruning.



Open-centre, established-spur pruned.

Open-centre, renewal pruned.



Regulated.

Fig. 3.

Seven-year-old deblossomed trees of Cox's Orange Pippin on M.II after pruning and before carrying their first crop; compare the bottom tree with the regulated tree in Fig. 2.

TABLE II.

TOTAL SHOOT GROWTH PER TREE (TO NEAREST METRE) OF WORCESTER PEARMAIN AND COX'S ORANGE PIPPIN ON MALLING SERIES, 1946-51.

Trial.	Treatment.					Sig. ratio ($P=0\cdot05$).
1	Reg.	OE	DE			
Worcester Pearmain on M.IV ..	103	120	132			*1·17*
3	Reg.	OR	DR	OE	DE	
Cox's Orange Pippin on M.II ..	200	247	255	266	332	*1·2*

The weight of new and old pruning wood was recorded. This record overlapped and later replaced shoot growth records. The data substantiate those for shoot growth and the following figures illustrate the ratio of new to old wood prunings for the three methods of pruning :

Regulated.	Renewal.	Established-spur.
1 : 1	2 : 1	3 : 1

Fruit buds.

The total number of fruit buds formed by open-centre and delayed open-centre trees of Worcester Pearmain was much the same, but regulated trees formed more than twice as many fruit buds as open-centre trees on the Lowlands Series and nearly three times as many on the Malling Series.

With trees of Cox's Orange Pippin also, the total number of fruit buds formed by both open-centre and delayed open-centre trees was very similar. Renewal pruned trees formed more fruit buds than established-spur pruned trees, though this difference was less marked on the Lowlands Series (Table III). Regulated trees of this variety on the Malling Series formed the greatest number of fruit buds ; there were no regulated trees of Cox on the Lowlands Series.

TABLE III.

COX'S ORANGE PIPPIN ON M.II. MEAN NUMBER OF FRUIT BUDS PER TREE, 1946-51.

Trial.	Soil series.	Treatments.				
		OE	OR	DE	DR	Reg.
3	Malling	515	1,087	505	999	1,957
4	Lowlands	464	627	467	528	—

Premature fruit drop.

In July, 1952, severe fruit drop occurred from trees of Cox's Orange Pippin. This was after the June drop and was possibly aggravated by the dry weather which occurred in June and July. The drops were recorded from each tree in Trial 3 and they have been expressed as a percentage of the total number of both dropped and harvested fruits. There was little difference between open-centre and delayed open-centre trees with the same pruning treatment, but the percentage drop was less where trees had been regulated or renewal pruned :

	Reg.	OR.	DR.	OE.	DE.	
Per cent drop	32·3	46·9	49·5	89·0	93·6	($P=0\cdot05$)

Fruit yield.

It was not found necessary to thin the fruits in any of the trials. The total fruit yield per tree under the different pruning treatments is shown in Table IV.

TABLE IV.

TOTAL FRUIT YIELD PER TREE (LB.), 1948-52.

Trial.	Soil series.	Variety and rootstock.	Treatments.					*Sig. diff.* $(P=0\cdot05)$.
			OE	DE	OR	DR	Reg.	
1	Malling	Worcester Pearmain on M.IV ..	70·1	67·0	—	—	155·6	*16·2*
2	Lowlands	Worcester Pearmain on M.IV ..	43·6	41·6	—	—	87·0	*12·1*
3	Malling	Cox's Orange Pippin on M.II ..	46·2	41·5	112·8	104·1	184·3	*24·4*
4	Lowlands	Cox's Orange Pippin on M.II ..	48·8	47·8	55·5	50·8	—	*n.s.*

In Trials 1 and 2 with Worcester Pearmain, regulated trees yielded more heavily each year and gave twice the total crop of other treatments on both soils ; there was no significant difference between open-centre and delayed open-centre trees.

With Cox's Orange Pippin in Trial 3 on the Malling Series there was no difference in crop between open-centre and delayed open-centre trees given the same pruning treatment. Renewal pruned trees bore more than twice as heavily and regulated trees four times as heavily as established-spur pruned trees.

In Trial 4, however, on the sandy Lowlands Series soil, the renewal pruned trees bore little more than the established-spur pruned ones. This is thought to be due to the effects of two severe summer droughts, recorded in 1947 and 1949, which resulted in scarcity of renewal wood, many trees being considerably stunted in growth. Trees of Worcester Pearmain, however, appear much more tolerant of drought conditions as they have grown away satisfactorily ; even the lightly pruned regulated trees, although their crops have been much below those for similar trees on the Malling Series, have behaved well (Table IV).

Established-spur pruned trees of Cox's Orange on the Lowlands Series cropped about the same as those on the Malling Series, whereas the crop from the renewal pruned trees was only half as much. The established-spur pruned trees on the Lowlands Series were much behind those on the Malling Series at the end of 1950, but during the last two years they more than made good the difference.

Fruit size.

Fruit size over the period, as shown by the mean weight of 100 apples, is given in Table V for Worcester Pearmain. The fruit on regulated trees tended to be smaller than those on established-spur pruned trees—doubtless owing to the much lighter crop of the latter. There was no significant difference between open-centre and delayed open-centre trees.

TABLE V.

FRUIT SIZE, WORCESTER PEARMAIN ON M.IV. (WT. OF 100 FRUITS IN LB.).

Trial.	Soil series.	Treatment.			*Sig. diff.* $(P=0\cdot05)$.
		Reg.	OE	DE	
1	Malling	19·5	23·1	22·9	*0·9*
2	Lowlands	21·0	21·9	22·5	*1·1*

On the Malling Series, regulated trees of Cox's Orange Pippin (Trial 3) yielded significantly smaller fruits than those under other pruning treatments, the mean weight (lb.) per 100 apples being :

Regulated.	Other treatments.	
23·8	26·0	$(P<0\cdot05)$

The fruit from the regulated trees was, however, well up to market requirements despite absence of fruit thinning.

There was no significant difference in size of fruit from any of the treatments on trees of Cox's Orange Pippin on the Lowlands Series (Trial 4).

Deblossomed trees.

To demonstrate the effect of different pruning treatments without the interacting effect of fruiting, a small number of regulated and open-centre renewal and established-spur pruned trees of Cox's Orange Pippin on M.II, adjoining those in Trial 3, were deblossomed by hand each spring for the first six years after planting. They were then allowed to crop.

Deblossomed trees, photographed after pruning and before the season in which they were allowed to crop, are shown in Fig. 3. It is clear that regulated pruning has given the largest tree and that the open-centre renewal pruned tree is larger than the open-centre established-spur pruned tree. In fact this again shows that the harder the pruning the more restrictive the effect is likely to be.

TABLE VI.

FIRST CROP FROM 7-YEAR-OLD DEBLOSSOMED TREES OF COX'S ORANGE PIPPIN ON M.II COMPARED WITH TOTAL CROP FROM TREES ALLOWED TO CROP NORMALLY.

	OE	OR.	Reg.
Total accumulated crop (lb.) from trees allowed to crop normally . .	46·2	112·8	184·3
First crop from deblossomed trees, in seventh year	3·2*	91·8	176·1
Difference	43·0*	21·0	8·2

* See text.

The first crops from deblossomed open-centre renewal pruned and regulated trees were very nearly as heavy as the accumulated crop over the first seven years from similar trees that were not deblossomed but allowed to fruit each year (Table VI). The crop on the open-centre established-spur pruned trees was severely affected by the premature fruit drop referred to earlier.

Discussion.

In these trials there has so far been little difference in performance between the open-centre and delayed open-centre trees of either Cox's Orange Pippin or Worcester Pearmain.

In the trial with Cox's Orange Pippin on the Malling Series the renewal pruned trees have, up to the present, given more than twice the crop of established-spur pruned trees ; on the Lowlands Series, however, where conditions are poor, there has been no difference in yield. An even greater increase in crop—four times that of the established-spur pruned trees—was obtained by using the regulated method, which involves much lighter pruning than does the renewal. In the trials with Worcester Pearmain the regulated trees have so far cropped twice as heavily as the established-spur pruned trees on both soil series ; there were no renewal pruned trees in these trials. Up to the present the fruit from regulated trees has been of good size and quality.

The simplicity of the regulated method, the speed with which it can be carried out, and the satisfactory crops resulting from its use so far are valuable attributes of a pruning system, and the method seems well worth while for temporary or filler trees, since in these cases there is no point in building up an elaborate open-centre or delayed open-centre framework. Regulated trees appear unorthodox in shape but they make efficient use of the ground and give the high productivity and early bearing required of fillers. The method cannot, however, be recommended for permanent trees until further experience has shown whether it is possible to maintain adequate growth and fruit size with such a light pruning method. At the moment it is being tested on permanent trees of a number of different dessert varieties worked on a wide range of rootstocks comprising the new Malling-Merton as well as some of the original Malling rootstocks (Preston, 1953).

The renewal method, under good growing conditions (Trial 3), has given better results for Cox's Orange Pippin than established-spur pruning and would seem well suited for permanent trees. It appears to be rather more difficult to carry out and takes a little longer than established-spur pruning (Rogers and Preston, 1947), and care has to be taken to ensure a supply of new laterals.

The trees of Cox's Orange Pippin that were deblossomed during the first six years from planting and allowed to crop in their seventh year have shown that it is possible to secure in that one year very nearly the same amount of fruit as was accumulated over the same period by comparable trees that were not deblossomed. The deblossomed regulated trees in particular have formed large frameworks for future cropping and now look as if they may far outcrop comparable regulated and renewal pruned trees that were not deblossomed. Thus this unconventional method of tree-building has not only resulted in an excellent framework (compare Fig. 3, bottom photograph, with trees in Fig. 2) but it has not, except with the open-centre established-spur pruned trees, involved any appreciable loss of crop. Such a treatment might suit the established grower who may be less concerned in securing the relatively smaller crops from trees during their early years than the new grower with perhaps limited capital. Chemical methods of deblossoming, however, without undue risk of damage to the foliage, would probably be necessary if this method were to be considered by the fruitgrower for use on a large scale.

Acknowledgements.

The writer wishes to thank Mr. N. H. Grubb for much helpful discussion and also members of the Statistical Section for their assistance.

Summary.

Winter pruning trials have been in progress since planting on apple trees planted in 1945-46 on two soil series. Treatments include open-centre and delayed open-centre shapes, and established-spur, renewal and regulated methods of pruning. Results are given for the first seven years after planting in so far as they relate to Worcester Pearmain and Cox's Orange Pippin.

Data are presented showing the effect of the different treatments on vigour, fruit bud formation, premature fruit drop, fruit yield, and fruit size.

Trees pruned to the delayed open-centre shape have so far shown no special advantages over open-centre trees.

At the end of the seventh year from planting renewal pruned trees of Cox's Orange Pippin on the Malling Series had yielded more than twice as heavily, and regulated trees four times as heavily, as established-spur pruned trees. On the Lowlands Series there was no difference between the yield from renewal pruned and the established-spur pruned trees. Regulated trees of Worcester Pearmain cropped twice as heavily as established-spur pruned trees on both soil series.

Trees on the Malling Series yielded more heavily than those on the Lowlands Series except in the case of established-spur pruned trees of Cox's Orange Pippin.

Premature fruit drop on Cox's Orange Pippin in the dry season of 1952 was progressively less with the lighter methods of pruning.

Some trees of Cox's Orange Pippin, deblossomed for six years, were allowed to crop in their seventh year. For renewal pruned and regulated trees this crop was almost as heavy as the accumulated crops, over the whole seven years, from similar trees that had not been deblossomed.

The results are discussed. The regulated method would appear to be well worth while for temporary trees, but further work is necessary before it can be recommended for permanent trees.

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PRELIMINARY STUDIES ON THE RESISTANCE OF RASPBERRY VARIETIES TO SPRING FROSTS

By J. P. RUXTON and IRENA MODLIBOWSKA

Raspberries, although one of the latest flowering fruit plants, may suffer considerable damage from frost in a bad year, especially in Scotland and the North of England.

Previous reports on the relative susceptibility of raspberry varieties to damage by spring frosts have all been based upon field observations. Both the early flowering varieties Lloyd George and St. Walfried are regarded by many as being very susceptible, but the former shows a marked tendency to recover by forming late-fruiting secondary laterals (Bush, 1945 ; Wood, 1950a and 1950b ; Cadman and Wood, 1951 ; Wood, 1952). Malling Promise and Malling Exploit were reported as badly damaged by wind frosts in Scotland in 1950 (Wood, 1950a and 1950b). Malling Promise when damaged breaks buds low down on the canes and recovers well (Wood, 1950a). The later flowering variety Malling Jewel tends to escape frost damage (Cadman and Wood, 1951 ; Wood, 1952). Oldham (1946) states that Norfolk Giant was conspicuous in 1938 as it ' proved to resist frost well ', probably because of its late flowering habit.

Material and methods.

A number of varieties of raspberry and the loganberry were tested in a special frost chamber, using either plants grown in pots or racemes cut from plants growing in the field. A random sample of ten racemes of each variety was subjected to controlled low temperature conditions as described for black currants (Modlibowska and Ruxton, 1953). In 1949, however, they were not sprayed with water before freezing and are referred to as ' dry ' racemes. In subsequent years, to reduce supercooling, the racemes were cut back about 1 inch under water and sprayed with water before freezing ; these are referred to as ' wet ' racemes. Plants in pots were also tested in a manner similar to that described for black currants. In 1952 the records of damage on potted plants were taken two to three weeks after treatment so that damage to buds could be determined without removing them from the parent plants.

Damage to both buds and flowers was determined by the discoloration of the drupels.

Results.

' Dry ' racemes.

In experiments 1, 2, and 3, carried out in June 1949, with ' dry ' racemes, seven Malling varieties, Enterprise, Exploit, Jewel, Landmark, Notable, Promise, and Seedling ' G ', were compared with the old-established commercial varieties Newburgh and Norfolk Giant. These racemes were exposed to —2·8° C. (27·0° F.) to —3·1° C. (26·4° F.) for 90 minutes.

The results (Table I) show that Seedling ' G ', Jewel, and Enterprise were least damaged, and Newburgh and Landmark most damaged. There were no indications of any one stage being consistently less damaged than the others.

' Wet ' racemes.

Experiments 4 to 7, made with ' wet ' racemes, included the new Malling seedlings ' V ', ' W ', ' Y ', and ' Z ', a new virus-free stock of Lloyd George, the Malling varieties Enterprise, Exploit, Landmark and Promise, and Newburgh, and Norfolk Giant. The first three of these experiments were carried out in 1950 and the fourth in 1951.

In these experiments the degree of exposure to low temperature conditions was progressively reduced from a minimum of —3·0° C. (26·6° F.), lasting for 60 mins. in experiment 4, to a minimum of —2·0 C. (28·4° F.) lasting for 30 mins. in experiment 7 (Table II). Damage was very severe, however, in all cases, the differences between varieties being relatively smaller than in 1949 for ' dry ' racemes. The wetting of the racemes was largely responsible for the increased damage—as has been found in many other experiments.

Whilst there was a tendency for the youngest green buds to be less damaged than the other stages, there was not much difference between later stages of development in the amount of damage suffered.

Table I.

Percentage of frost damage to nine raspberry varieties, using ‘ dry ’ racemes. Varieties arranged in order of increasing mean damage.

Experiment.	Minimum air temperature.	Duration of minimum air temperature. Mins.	Stage of development.	Malling Seedling ‘ G ’.	Malling Jewel.	Malling Enterprise.	Norfolk Giant.	Malling Notable.	Malling Promise.	Malling Exploit.	Newburgh.	Malling Landmark.
1 1st June, 1949	−2·8° C. (27·0° F.)	90	Buds	—	—	36·2	—	—	—	—	77·3	76·6
			Flowers	—	—	46·9	—	—	—	—	92·9	100·0
			Fruitlets	—	—	75·0	—	—	—	—	81·2	100·0
			Mean	—	—	46·4	—	—	—	—	82·7	89·7
2 2nd June, 1949	−3·1° C. (26·4° F.)	90	Buds	64·3	68·2	62·5	66·2	82·1	91·4	61·5	79·3	100·0
			Flowers	51·6	66·7	56·8	87·5	89·7	86·5	83·4	95·1	100·0
			Fruitlets	45·3	67·8	79·3	90·9	93·1	94·1	71·1	100·0	100·0
			Mean	51·8	67·5	65·0	71·1	87·3	89·9	74·1	91·1	100·0
3 9th June, 1949	−3·1° C. (26·4° F.)	90	Buds	28·9	22·2	45·5	46·9	44·4	33·3	—	43·3	92·9
			Flowers	30·5	31·6	39·4	31·6	31·6	49·0	—	51·7	95·8
			Fruitlets	28·9	25·4	45·1	62·5	32·4	43·5	—	58·5	100·0
			Mean	29·4	26·0	43·7	47·6	33·9	44·9	—	52·7	97·9

TABLE II.

MEAN PERCENTAGES OF FROST DAMAGE TO ELEVEN VARIETIES OF RASPBERRY, USING 'WET' RACEMES. VARIETIES ARRANGED IN ORDER OF INCREASING MEAN DAMAGE.

Experiment.	Minimum air temperature.	Duration of minimum air temperature. Mins.	Malling Enterprise	Malling Seedling 'V'.	Malling Seedling 'Y'.	Malling Promise.	Malling Seedling 'Z'.	Malling Seedling 'W'.	Newburgh.	Malling Exploit.	Lloyd George.	Norfolk Giant.	Malling Landmark.
4 30th May, 1950	−3·0° C. (26·6° F.)	60	50·0	—	93·5	92·1	88·7	—	83·1	91·0	97·3	—	97·8
5 5th June, 1950	−3·1° C. (26·4° F.)	30	78·5	95·8	88·5	77·3	69·1	85·6	84·8	89·5	88·0	94·2	95·4
6 6th June, 1950	−2·5° C. (27·5° F.)	2	81·3	65·4	69·8	87·1	86·7	87·6	87·8	85·5	71·7	82·4	82·0
7 13th June, 1951	−2·0° C. (28·4° F.)	30	93·7	82·7	77·1	73·0	87·5	83·8	89·6	82·2	95·6	92·5	87·1

Statistical analysis.

An analysis of variance was carried out on the mean percentage of damaged flowers on cut racemes for the varieties Lloyd George, Newburgh, Norfolk Giant, Enterprise, Exploit, Landmark, and Promise in experiments 2 to 7. The results (Table III) show that in general Enterprise was the least damaged and Lloyd George and Landmark the most damaged, but under the conditions of these experiments the differences were relatively small.

TABLE III.

COMPARISON OF MEAN PERCENTAGE OF FROST-DAMAGED BLOSSOM OF SEVEN OF THE VARIETIES OF RASPBERRY TESTED DURING 1949-51, USING CUT RACEMES.

Variety.	Experiment.						Mean.
	2 (1949)	3 (1949)	4 (1950)	5 (1950)	6 (1950)	7 (1951)	
Malling Enterprise	65·0	43·7	50·0	78·5	81·3	93·7	70·5
Malling Promise	89·9	44·9	92·1	77·3	87·1	73·0	79·1
Norfolk Giant	71·1	47·6	—	94·2	82·4	92·5	80·9
Malling Exploit	74·1	—	91·0	89·5	85·5	82·2	81·2
Newburgh	91·1	52·7	83·1	84·8	87·8	89·6	82·8
Lloyd George	—	—	97·3	88·0	71·7	95·6	86·5
Malling Landmark	100·0	97·9	97·8	95·4	82·0	87·1	94·9

Figures in brackets do not differ significantly (P=0·05).

Loganberry.

In all of the above experiments racemes of loganberry were included for comparison. The results showed that in general the damage to cut racemes of the loganberry was comparable to that occurring to the middle group of the varieties of raspberry tested.

Plants in pots.

Experiment 8 (1951) and experiments 9 and 10 (1952) were carried out with potted plants of the varieties Lloyd George, Norfolk Giant, and the Malling varieties Enterprise, Exploit, Landmark, and Promise. Two plants of each variety were frozen in each experiment and two plants were used as controls. In experiments 9 and 10 the control plants of each variety were common to both experiments. Records were made of damage at the different stages of development, while in experiments 9 and 10 a crop record was also taken. Two different methods of recording the stage of development were used.

In experiment 9, because no flowers were open at the time of freezing, the length of the raceme and the degree of separation of the buds were used as the criteria of the stage of development. The categories used were as follows :

NV—raceme still in the bud stage in the axil of the subtending leaf, the fruit buds not yet being visible.
NS—raceme somewhat more developed, the buds visible but not distinctly separated.
S<10 cm.—the buds separated and the raceme up to 10 cm. long.
S>10 cm.—the raceme more than 10 cm. long.

In experiment 10, carried out 23 days later, the categories used were :

A—racemes bearing buds only.
B—racemes bearing flowers and earlier stages.
C—racemes bearing fruitlets and earlier stages.

Lloyd George, Exploit, and Promise were the earliest flowering of the varieties tested, Enterprise and Landmark followed, whilst Norfolk Giant was the latest flowering variety with no fruitlets and only a few flowers open.

Some frost damage was recorded on the control canes in experiments 9 and 10 ; this was probably due to the frost of 3rd April, when the air temperature fell to $-2{\cdot}2^\circ$ C. ($28{\cdot}0^\circ$ F.) for about two hours. This damage, as well as the total damage recorded after the experimental freezing, is shown in Table IV, and ' net damage ' figures, obtained by deducting the percentage of damage to controls from that to the experimentally frozen plants, are also given.

TABLE IV.

PERCENTAGE OF FROST DAMAGE TO RASPBERRY VARIETIES GROWING IN POTS. VARIETIES ARRANGED IN ORDER OF FLOWERING.

Experiment.	Minimum air temperature.	Duration of minimum air temperature. Mins.	Stage of development.	Lloyd George.	Malling Exploit.	Malling Promise.	Malling Landmark.	Malling Enterprise.	Norfolk Giant.
8 11th June, 1951	−2·0° C. (28·4° F.)	30	Green buds	32·6	29·4	9·1	23·5	19·6	0·0
			White buds	100·0	50·0	50·0	50·0	0·0	—
			Open flowers	89·5	78·6	100·0	73·9	50·0	—
			Petals fallen	100·0	100·0	100·0	100·0	100·0	—
			Fruitlets	100·0	100·0	100·0	100·0	100·0	—
			ALL STAGES	**67·4**	**65·0**	**46·6**	**42·3**	**44·8**	**0·0**
9 29th April, 1952	−3·0° C. (26·6° F.)	45	*						
			NV	—	—	0·0	—	0·0	0·0
			NS	75·0	50·0	0·0	40·0	30·4	0·0
			S<10 cm.	50·0	32·8	9·8	22·8	17·9	20·0
			S>10 cm.	14·4	13·4	11·5	33·9	21·2	27·6
			ALL STAGES	**16·0**	**17·0**	**10·9**	**31·2**	**19·1**	**9·6**
			Damage to Controls	14·2	14·6	5·9	5·4	7·9	3·1
			NET DAMAGE*	**1·8**	**2·4**	**5·0**	**25·8**	**11·2**	**6·5**
10 22nd May, 1952	−2·0° C. (28·4° F.)	2	*						
			A	—	13·9	44·8	16·4	34·3	4·6
			B	—	32·4	18·9	35·4	16·0	12·7
			C	—	52·4	60·0	40·9	55·6	—
			ALL STAGES	—	**43·8**	**53·1**	**31·8**	**39·4**	**6·7**
			Damage to Controls	—	14·6	5·9	5·4	7·9	3·1
			NET DAMAGE	–	**29·2**	**47·2**	**26·4**	**31·5**	**3·6**

* For explanation see text.

Norfolk Giant was least damaged in all three experiments. Experiment 8 shows a clear tendency for the last advanced varieties to be the least damaged, and for open flowers and later stages to be more susceptible to damage than buds. The results of experiments 9 and 10 are less clear cut, but experiment 10 suggests the same tendencies. Experiment 9 shows that very young buds enclosed in the leaf sheath are the least damaged. Unseparated buds on the younger racemes tend to be more damaged than separated buds on the older racemes. It will be noticed that the damage suffered by varieties in experiment 10 was greater than that suffered in experiment 9, despite the fact that the degree of exposure to low temperature was much reduced. This supports the suggestion that the more advanced a variety is in its flowering phase the more susceptible it is to frost damage. Thus it appears that the advancing season, with its steadily rising temperature, has a dehardening effect. It was found that in buds the reproductive organs were usually killed while the vegetative parts continued to develop and open.

TABLE V.

EFFECT OF FROST ON CROP.

Experiment.	Crop weight (per raceme) on frozen plants, as a percentage of that on controls.					
	Lloyd George.	Malling Exploit.	Malling Promise.	Malling Landmark.	Malling Enterprise.	Norfolk Giant.
9	78·1	81·9	75·8	67·7	77·6	100·5
10	—	93·9	55·5	54·7	72·8	158·5

The crop weight per raceme (Table V) is expressed as a percentage of that on the controls, to overcome differences in plant size. Exposure to low temperature reduced the crop except for Norfolk Giant where the frost damage did not exceed 10 per cent. An increase in frost damage resulted in a decrease in crop (except for Malling Exploit). This decrease was not always proportional to the damage, owing to such factors as a difference in fruit set (Enterprise), the number of fruits per raceme (Norfolk Giant), and the size of the fruits (Landmark).

Time of ripening was not delayed by exposure to low temperature.

Discussion.

These experiments show that none of the varieties tested was markedly resistant to frost. Temperatures of —2·0° C. (28·4° F.) and below caused sufficient damage in experiments with potted plants to reduce the crop in most of the varieties tested.

The raceme tests, where the varieties, at given stages of development, were evenly exposed to low temperature conditions on the rotating wheel, showed the basic resistance of varieties unaffected by such factors as the age of the flower, the shelter afforded by foliage, and the position of the racemes on the plant. In these tests Enterprise tended to be least damaged and Lloyd George and Landmark the most damaged, but often the differences were not large.

The differences in the results between tests with racemes and potted plants indicates the importance of factors other than that of basic resistance. The most striking example is given by Norfolk Giant, which in the cut raceme tests did not exhibit any special basic resistance, but in pot tests, as well as in practical experience, has proved to be least damaged ; this is probably due to its late flowering habit. In general, however, the relative resistance of varieties varies with the stage of development : the more advanced the variety is, the more susceptible does it appear to be to frost damage.

The lack of an exact proportional relationship between the amount of frost damage and the final crop indicates the importance of other factors on the cropping of a variety. Such factors as the ability of a variety to set fruit, the number and size of fruits per raceme, the number of racemes per cane, the tendency for new racemes to be produced in the place of damaged ones, and the ease with which fruiting racemes may be broken off, all influence to a greater or lesser extent the final crop. When frost damage is severe, however, this is the dominating factor and the crop is much reduced.

The protection afforded to buds and blossoms by foliage, and the height of them above the ground have not been investigated, but the same principles as those discussed in connection with black currants (Modlibowska and Ruxton, 1953) might be expected to apply in the case of raspberries. These points are most satisfactorily settled by field trials, and a variety trial of raspberries has been planted on some low-lying land at the Research Station in order to pursue these studies.

Acknowledgements.

The authors are indebted to Dr. W. S. Rogers for advice and criticism, to Miss N. J. Wallick, who took part in the early experiments, and to Mr. C. H. W. Slater for their valuable assistance.

Summary.

Preliminary laboratory investigations into the relative resistance of raspberry varieties to damage by spring frost showed that none of those tested was markedly resistant, although some varieties tended to be less damaged than others. Open flowers were more damaged than buds.

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PRELIMINARY STUDIES ON HERBICIDE APPLICATIONS IN RASPBERRY PLANTATIONS

By A. WAKIL* and D. W. P. GREENHAM

The cost of normal weed control operations amongst raspberries may represent a considerable part of the total crop production costs (Tubbs, 1954). It seemed worth while, therefore, to investigate both the possibility of achieving weed control entirely by chemical means, and the use of certain herbicides against particular weeds whose control in raspberry plantations is normally achieved by hand labour. Single plots were regarded as adequate for this preliminary study.

Material and treatments.

These studies were carried out in 1950 and 1951 at East Malling Research Station in a vigorous raspberry plantation of the varieties Malling Enterprise and Malling Landmark planted in 1946. The soil was a free-drained light loam, exceeding 4 feet in depth, of the Barming Series (Furneaux, 1954). Treatments were applied without replication, in one or other of two adjacent blocks of the plantation. Within each block the treatments, including a cultivated control, were assigned to the plots at random. The individual plots were 150 sq. yds. in area in one block, and 102 sq. yds. in the other. Each plot had two experimental rows with guard rows on either side, all rows being 6 ft. apart. Half the length of each row consisted of the variety Landmark and the other half of the variety Enterprise.

Attention was directed mainly to the control of grasses, and the following herbicides were tried with this object : DNC-fortified oil emulsions, TCA (trichloroacetic acid) (Farish and Leonard, 1948 ; Carter, 1949 ; Raynor, 1949), IPC or propham (o-*iso*propyl *n*-phenyl carbamate) (Templeman and Sexton, 1945 ; Lachman, 1948 ; Raynor, 1949), and maleic hydrazide or MH (1,2-dihydropyridazine-3,6-dione) (Currier and Crafts, 1950 ; Zukel, 1950). A further observation plot was treated with the sodium salt of MCPA (2-methyl-4-chlorophenoxyacetic acid), which is known to be effective against many broad-leaved weeds.

All applications were made by a knapsack sprayer, care being taken to wet the canes only at the base. The materials were applied in 100 gallons of water per acre except TCA which was applied in 200 gallons per acre.

Observations were made on the control of weeds and on the reaction of the raspberries. Crop weights were obtained from each plot.

Results.

DNC-fortified oil emulsions.

Oil emulsions fortified by DNC were applied on one plot four times during 1950. The emulsion used for the first application contained 0·5 per cent DNC and 20 per cent oil, but this emulsion proved to be unstable. A different stock was, therefore, used for the remaining three applications, of which two were made at 1 per cent DNC and 6·4 per cent oil, and one at 2 per cent DNC and 12·8 per cent oil.

None of the applications controlled the grass *Poa annua* which covered most of the ground. The treatment was, therefore, abandoned and the plot cultivated at the end of the growing season.

The fruiting canes showed no damage either at the bases, where they had been wetted by the emulsion, or at the tops. The 1950 crop of canes, however, was less vigorous than that of the control treatment, because the second application of this weedkiller, in May, killed many young canes, and the canes which grew subsequently had a short growing season. Despite this, however, the yield of fruit in 1951, as well as in 1950, did not compare unfavourably with that from the control plot.

TCA.

TCA was applied at 30 lb. per acre on 1st April, 1950. It killed most of the grass *Poa annua*, but did not eliminate it entirely. Cultivation was necessary to control the broad-leaved weeds which followed the killing of the grass.

Within three weeks of application, the raspberry leaves on the fruiting canes, as well as on the young canes, developed an interveinal type of chlorosis (Fig. 1). Growth of the young canes was

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* This paper is based on data reported by the first-named author (now in charge of the Agricultural Department, Helmand Valley Authority, Girishk, Kandahar, Afghanistan) in part of a London University Ph.D. thesis (1952) entitled ' Studies on the use of certain permanent mulches and weedkillers in fruit plantations '.

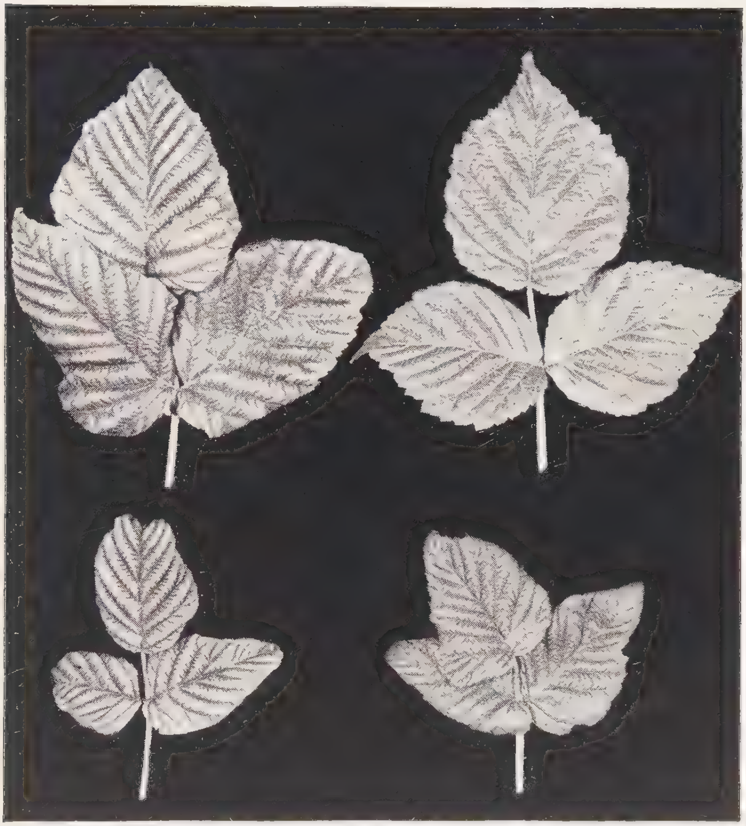

FIG. 1.

Effect on raspberry leaves of TCA applied to the soil at the rate of 30lb. per acre in 200 gallons of water in early April. *Left :* Leaves, photographed 19 days later, showing interveinal chlorosis. *Right :* Normal leaves.

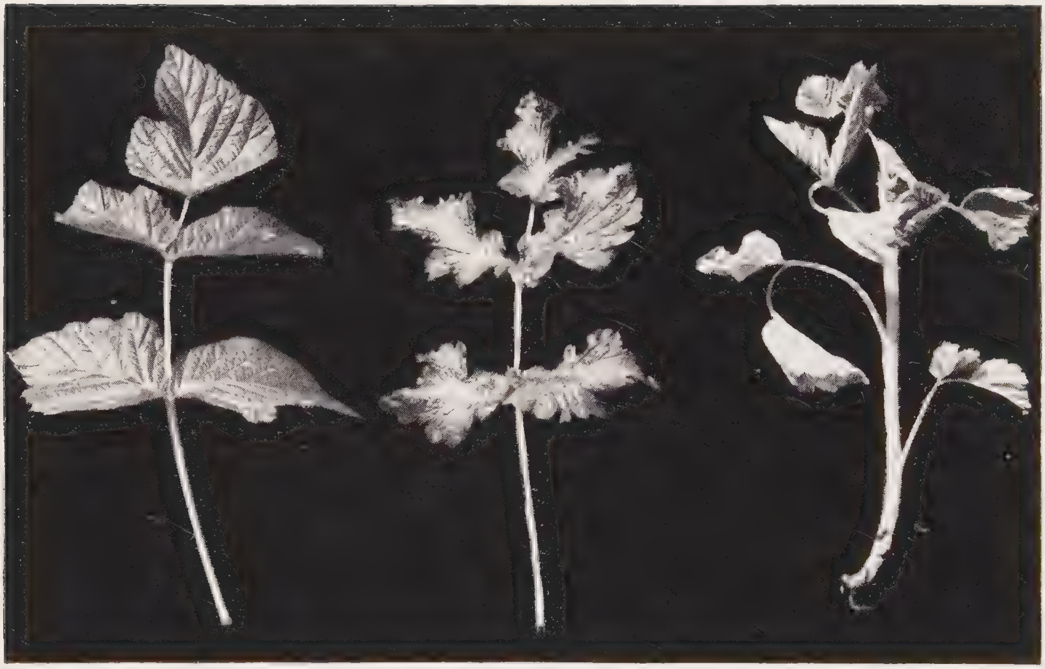

FIG. 2.

Effect on raspberries of 0·2 per cent acid equivalent solution of sodium MCPA, applied to the soil in 100 gallons of water per acre in late June, some of the new canes being wetted in the process. *Left :* Normal leaf. *Centre :* Abnormal leaf, after spray. *Right :* Young cane, after spray.

severely retarded and the yield of fruit seriously reduced both in 1950 and in 1951 as a result of this single application. The fruit, furthermore, was badly infected with mildew (*Sphaerotheca humuli* (DC.) Burr.).

There were indications from the literature (Carlson, 1949 ; Carlson and Moulton, 1949) that earlier applications might be more successful. The same treatment was therefore applied on 12th February, 1951, on another plot. The leaf symptoms were similar but less severe, and the reduction in cropping was again very large.

IPC.

IPC was applied on 20th March, 1951, at the rate of 15 lb. per acre. Owing to the limited amount of material available only two alleys covering a single raspberry row were treated.

The plot had been cleaned of weeds before application, and the herbicide kept the treated area devoid of grass by preventing the growth of seedlings. Broad-leaved weeds grew in the plot, however, so that cultivation was necessary again on 4th June.

No effect of this herbicide on the raspberry canes was observed until the beginning of June, when the leaves of the treated plants became somewhat darker in colour and cane growth was checked. This check lasted for about 40 days, after which the canes seemed to be growing normally again and probably at a greater rate than the untreated canes, so that in the autumn no difference could be observed between the vigour of the treated and the untreated rows. The yield of fruit from the treated row was lower than that from the untreated rows, and it is of interest to note that the check to cane growth coincided with the fruit-picking season.

Maleic hydrazide.

Maleic hydrazide was applied at 2 lb. per acre on 21st May, 1951, on the alleys of a plot which was cultivated soon after application. No effect was observed either on the new canes which were wetted by the spray or on the older canes. The yield of fruit did not appear to be depressed.

MCPA.

Most of the weeds present were not of the type susceptible to the synthetic growth regulating weedkillers, so the MCPA plot was kept cultivated and observations were restricted to the effect on the raspberries. Two applications of the sodium salt of MCPA were made each year, in 1950 on 1st April and 6th September, and in 1951 on 10th May and 24th June. Except for the last application, which was at 2 lb. acid equivalent per acre, all the other applications were at 1 lb. per acre.

Applications at the lower rate caused some distortion in the young canes but this disappeared after a time. MCPA at 2 lb. per acre, however, caused severe distortion and abnormality in the leaves of a few of the younger canes which were wetted by the spray (Fig. 2). Even these canes recovered after some time. No effect of the treatment was found on the old canes, either through the soil or by translocation through the young ‘ spawn ’. The cropping data suggested that the treatment had no very serious effect on the fruitfulness of the canes.

Discussion and conclusions.

It has not been possible to study the advantages and disadvantages, from a soil management point of view, of maintaining a bare but uncultivated soil surface, because such a system has not been achieved. Oil emulsions fortified by DNC were found to be ineffective against grasses, including *Poa annua*. Of the other materials which might be useful for the control of grasses, no definite conclusions can be drawn regarding the effects of IPC or maleic hydrazide on the raspberry plants, while spring applications of TCA applied in February and April were harmful. With regard to the use of TCA in America, however, Carlson (1949) states that grass in raspberries is controlled with safety if applications are made in the autumn. Carlson and Moulton (1949) applied TCA at 10, 30, and 60 lb. per acre to dormant raspberry plants and found no signs of injury the following spring, but by July the leaves showed a slight chlorosis which was most pronounced with the higher concentrations. They found spring applications to cause more severe chlorosis and some marginal burning of the newly opened leaves, while TCA applications in summer had even more serious effects. It would appear that TCA should not be dismissed as harmful to raspberries without an investigation of the effect of autumn applications under our conditions.

Considering the present observations on the effect of MCPA together with reports of experience elsewhere on the use of 2,4-D (2,4-dichlorophenoxyacetic acid) amongst raspberries, it appears that the growth-regulating type of herbicides (Davidson, 1949 ; Freeman *et al.*, 1951) might be worth further investigation in relation to specific weed problems. For instance, MCPA or 2,4-D might prove useful commercially, as a supplement to the usual cultivations, for controlling weeds such as bindweed

(*Convolvulus arvensis*). The success of such treatments probably depends on spraying in such a way as not to allow spray drift to fall on the raspberry leaves. Apart from these special problems, MCPA or 2,4-D might also find a use in general weed control in raspberries by applications designed to inhibit the germination of weed seeds or kill very young seedlings. For this purpose, SES (sodium 2,4-dichlorophenoxyethyl sulphate), also known as E.H.1, is also worth considering, since this material apparently does not become active until it is in contact with the soil, and has been found effective in America (Nylund *et al.*, 1951) for the control of annual grasses amongst raspberries.

Acknowledgement.

Acknowledgement is due to members of the A.R.C. Unit of Experimental Agronomy, Oxford, for helpful advice regarding herbicide treatments and for supplying materials.

Summary.

Observation studies, using unreplicated plots, were carried out in a 4-year-old plantation of raspberries of the varieties Malling Enterprise and Malling Landmark. DNC-fortified oil emulsions failed to control grasses. Spring applications of TCA caused chlorosis of the raspberry leaves and reduction of cropping. There was evidence that IPC checked the growth of raspberries. Maleic hydrazide showed no such effect. MCPA, when applied at 1 and 2 lb. acid equivalent per acre to the soil with care to avoid drift, caused distortion of the young canes, but had no serious effect on cropping.

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A SPORT IN THE APPLE ROOTSTOCK MALLING XIII

By **R. J. GARNER** and **ELIZABETH KEEP**

In the autumn of 1953 it was noticed that one of several lined out sets of rooted shoots of M.XIII apple rootstock had made much less growth than the others (Fig. 1). In general appearance the typical characteristics of this stock were clearly displayed in shoot and leaf colour, and in general habit, but there were differences in leaf texture and serration which suggested that a sport had occurred. Accordingly, young root tips were collected for cytological examination, and measurements were made of the shoots, leaves, and petioles.

M.XIII was originally propagated from a seedling selected by Messrs. Späth of Berlin, and added by Hatton to his collection of apple rootstocks in 1914 (Hatton, 1927). In extended trials with various scion varieties it proved inferior to other rootstocks of its class, and consequently output at East Malling was curtailed and reduced eventually to the product of some twenty stools. It was the progeny of ten of these, including the variant, which had been lined out separately in January 1953.

Cytology.

Root tips, collected from the variant and a normal stool of M.XIII in October 1953, were fixed in Navashin's fluid and embedded. Sections were cut at 8μ and stained by a chromic acid modification of the crystal violet method (La Cour, 1937). Chromosome counts showed that the roots of the normal plant were diploid ($2n=34$), and those of the mutant tetraploid ($2n=68$). (See Fig. 2.)

External characters.

Shoots.

The ten longest shoots from the normal clone and from the sport were selected for measurement. The latter were little more than half the length of the normal and considerably thicker in relation to their length (Table I). The internodes on the sport were shorter, though there were more nodes on the normal shoots. The apical and basal inch of each shoot, where the nodes were congested and indefinite, were not included in the records.

Leaves.

Six leaves—the 4th, 8th, 12th, 16th, 20th and 24th from the apex of each of the ten shoots recorded, were detached and measured. The laminae of the sport were smaller, the serrations more finely divided (Fig. 3), and the leaf texture considerably more harsh than the normal. The ratio of lamina length to width is approximately equal in each clone (Table I). Petiole length is strikingly different in the two clones, those of the sport being markedly shorter.

TABLE I.

EXTERNAL CHARACTERS COMPARED.

Clone.	Shoots.				Leaves.			
	Length. cm.	Diameter at middle. cm.	Length/Diameter.	Internode Length. cm.	Length. mm.	Width. mm.	Length/Width.	Petiole Length. mm.
Normal ..	83·30	0·640	130	1·73	68·68	50·77	1·35	13·17
Sport ..	47·90	0·617	78	1·43	58·38	43·35	1·34	8·47

Discussion.

This is the first sport reported, so far as we know, in any clonal apple rootstock. Previously reported bud sports of diploid apple varieties, in which spontaneous chromosome doubling has occurred, have been cyto-chimaeras in which certain tissues only are tetraploid (Blaser and Einset, 1948; Darrow *et al.*, 1948).

In this case, no significant difference in size was found between stomata on the lower epidermis of the leaves of these clones which suggests that the epidermis of the sport may be diploid, although larger stomata are not an invariable criterion of tetraploidy (Dermen, 1951).

Further cytological studies are in progress.

Acknowledgement.

We are indebted to Mr. T. V. Dixon for first drawing our attention to the sport.

Summary.

A sport found in the vegetatively propagated apple rootstock M.XIII is described. Chromosome counts show that the roots of the normal clone are diploid, those of the sport tetraploid. The similarity in size of the stomata of both suggests that the epidermis of the sport may be diploid.

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A Sport in the Apple Rootstock Malling XIII.
By R. J. Garner and Elizabeth Keep

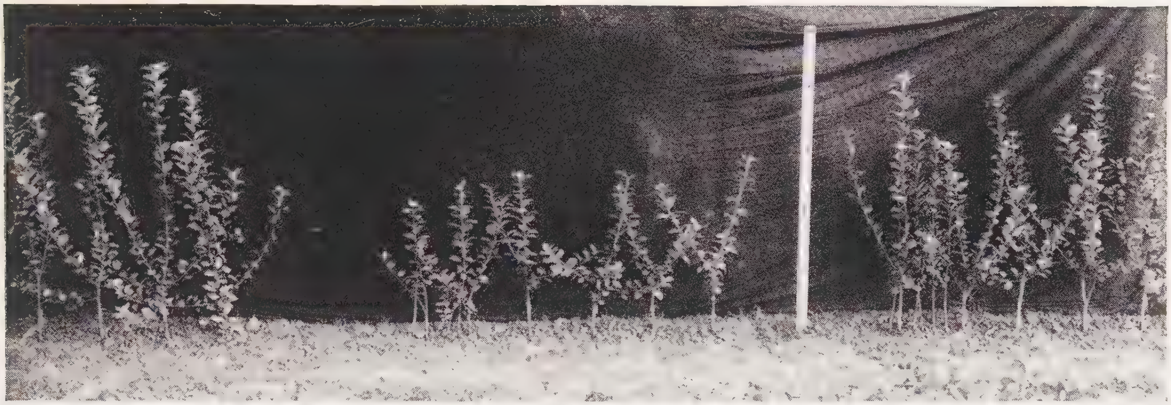

Fig. 1.
M.XIII apple rootstocks after one season's growth from rooted layers.
Left.—Normal plant. *Centre.*—Sport. *Right.*—Normal plant.

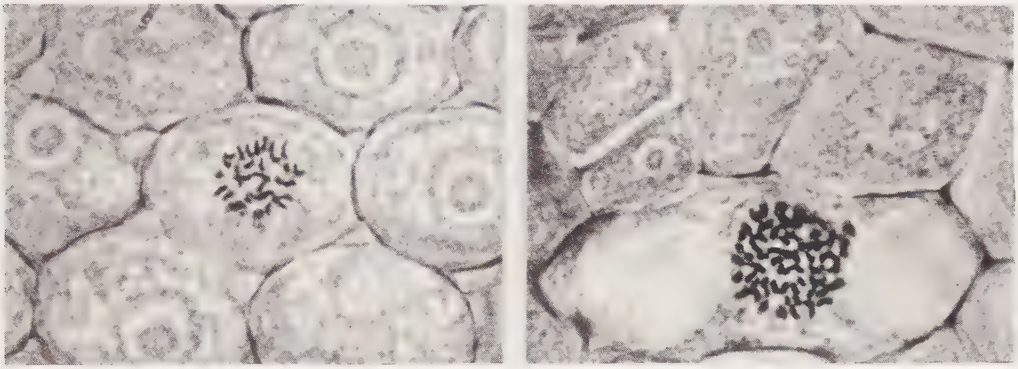

Fig. 2.
Cells from root tips of M.XIII apple rootstocks.
Left.—Normal plant—diploid ($2n=34$). *Right.*—Sport—tetraploid ($2n=68$).
(enlarged × 1500)

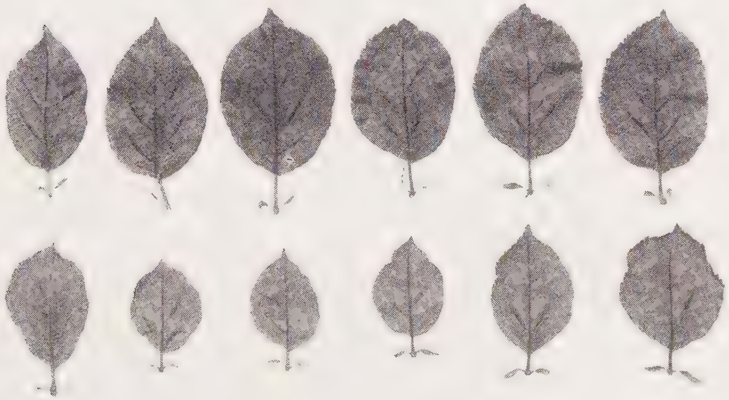

Fig. 3.
Leaves from shoots of M.XIII apple rootstocks.
Top row.—Every fourth leaf, counting from the apex, from a shoot of a normal plant.
Bottom row.—The same, from shoot of sport. Note the fine serrations and short petioles.

NOTE ON THE EFFECT OF A SYNTHETIC SOIL CONDITIONER, CRD 189*, ON THE WATER RELATIONSHIPS OF A FINE SANDY LOAM

By J. E. GOODE

The effects of two soil conditioners, CRD 189 and CRD 186†, on aggregation, aeration, and water relationships of the soil have been described by Hedrick and Mowry (1952) as increasing the aggregate stability, improving infiltration, percolation, water holding capacity, and aeration, whilst decreasing evaporation of water from the soil surface. More recently Jamison (1953) has reported on the effects of CRD 186 on soil air and water relationships of a number of soils covering a wide range of texture. He concludes that structural improvement of a soil generally increases air capacity and decreases available water capacity, but he adds that under field conditions the soil water relationships are generally improved because the effective capacity of a dry soil to absorb water from short heavy rains would increase with structural improvement.

Bould and Tolhurst (1953) have described the effects of both CRD 189 and CRD 186 on nutrient availability.

Soil moisture tension, rather than the amount of available water, probably becomes the limiting moisture factor for maximum growth and development of plants, since tension is the property of soil water directly related to the work plants must do to extract water from the soil (Richards and Wadleigh, 1952).

In April, 1952, it was therefore decided to use soil moisture tensiometers in a field study of the moisture conditions of a fine sandy loam, having a clay content of between 13 and 16 per cent, as affected by the addition of CRD 189.

Layout and methods.

The number and replication of treatments were restricted by the amount of the soil conditioner available for use and it was only possible to provide two replicates of each of three treatments, one of which was the control. This limited replication makes it necessary to exercise caution in the interpretation of the results.

After preliminary tests with two rates of application at 0·05 per cent and 0·1 per cent, it was decided to use only the higher rate since this gave most satisfactory aggregate stabilization.

A uniform piece of soil was divided into experimental plots 2 yds. × 2 yds. and cultivated uniformly except for the application of the polymer. The conditioner was incorporated to 3 in. and 9 in. depth on two plots each and these were compared with two control plots, the trial being completely randomized. All plots were maintained free of weeds by frequent light hoeing.

Before the conditioner was applied on 30th April, 1952, the soil was worked to a fine tilth on all the plots, incorporation being carried out when the soil was in an easily workable state. Fairly heavy persistent rain occurred three days after the conditioner was applied.

In one plot of each treatment two tensiometers were installed, one at 12 in. before the treatments were applied, and one at 5 in. after the 9 in., but before the 3 in., incorporations had been carried out. These two tensiometer depths were chosen to give an indication of the changes in tension through the top soil due to evaporation loss from and rainfall additions to the soil.

Soil samples were taken at frequent intervals with a $\frac{3}{4}$-in. auger during the summer of 1952, and moisture contents determined.

Soil moisture tensions.

Figures 1 and 2 show the soil moisture tensions, in centimetres of mercury, plotted from readings taken every two or three days during the summers of 1952 and 1953. The amount of rain over these same periods is also shown. Tensions during May and early June of 1952 have not been included because during this time the soil was settling and attaining equilibrium. It was observed that immediately after incorporation of the conditioner the tensions on the treated plots rose rapidly and then fell slowly with successive rainfalls to give the consistent pattern shown in Figs. 1 and 2.

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* The sodium salt of hydrolysed polyacrylonitrile.

† A vinyl acetate maleic acid co-polymer.

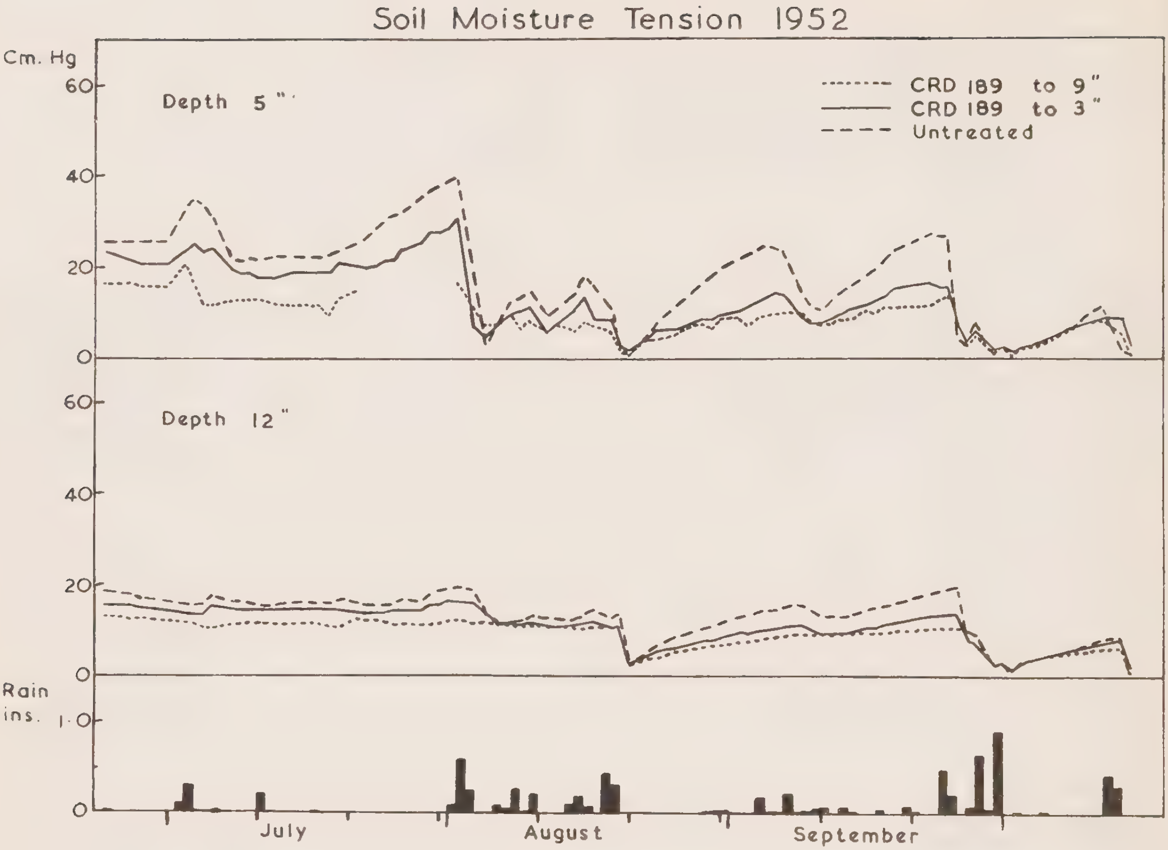


FIG. 1.

The greatest fluctuations in soil moisture tension occurred in the untreated plot and the least in the 9 in. treated soil. The 3 in. treated soil appeared to be intermediate between the other two treatments in 1952, but in 1953 conformed much more closely to the untreated soil. This suggests a deterioration in the soil moisture relationships of the shallowly conditioned soil, possibly brought about by the frequent surface cultivations which were necessary to maintain the plot surfaces free from weed growth. However, during the dry period from 22nd June to 7th July, 1953, when the moisture tension in the untreated soil increased rapidly to the maximum of the tensiometers at both 5 in. and 12 in. depths the tension in the 3 in. treated soil at 12 in. depth only reached a maximum of 23 cm. Hg. Unfortunately the tensiometer at 5 in. depth required refilling at this time and the soil moisture tension could not be obtained.

The effect of rainfall in reducing tensions was about the same under all treatments, but in 1953 at the end of the dry spell on 7th July there was a three to four day lag between the rewetting of the treated and untreated soils.

At 12 in. depth the soil moisture tension in the 9 in. treated soil fluctuated about the field capacity value, whilst in the other two treatments fluctuations were between field capacity and tensions approaching 20 cm. Hg. This is regarded as a critical tension at which soil moisture can become a limiting factor for maximum growth and development of fruit plants and, since many plants have an extensive part of their root systems at about 12 in. depth, this effect of deep incorporation of a soil conditioner on soil moisture tension may be of some practical importance in the growth of plants.

Soil moisture content.

Soil moisture contents calculated on a weight basis were greater in the conditioned than in the untreated soil. Differences between treatments were apparent to a depth of 12 inches but not below

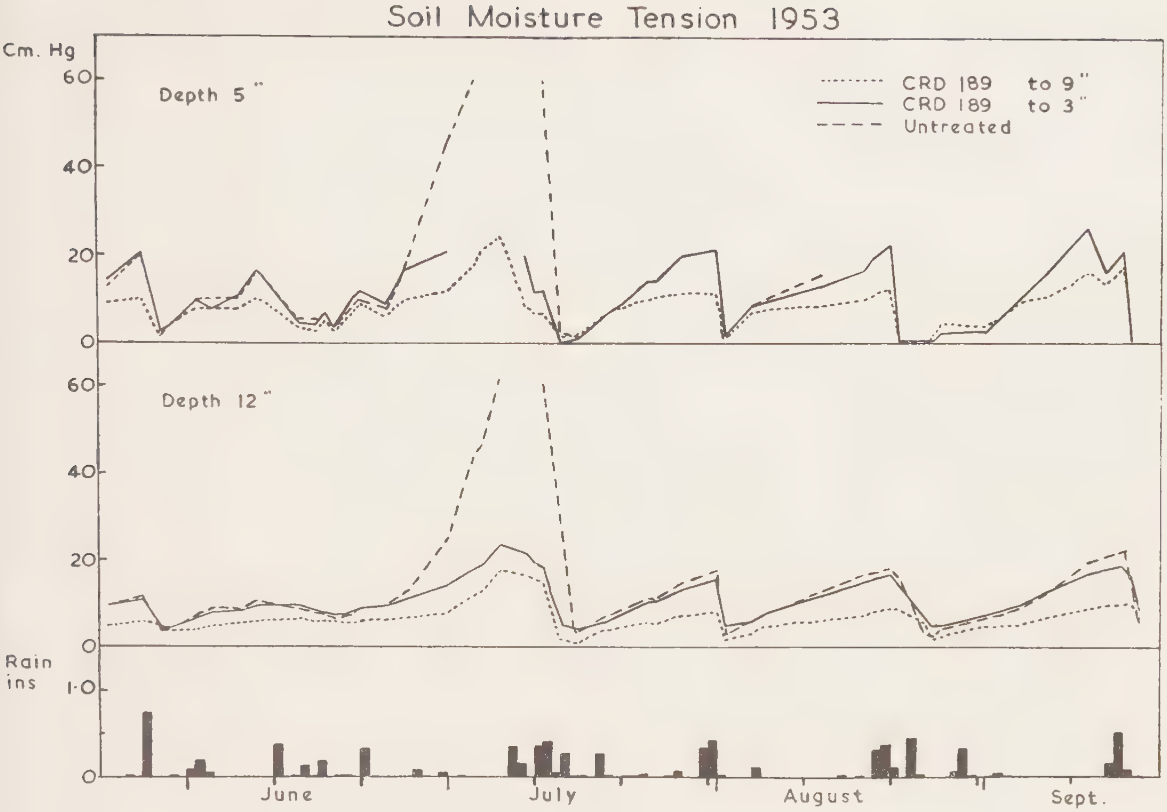


FIG. 2.

this depth. However, the mean moisture content, calculated as per cent dry soil of a 12-inch depth of soil at field capacity for each of the three treatments, showed that only the deep incorporation of CRD 189 differed significantly from the untreated soil.

	Moisture per cent dry soil.		
	CRD 189 to 9 in.	CRD 189 to 3 in.	Untreated.
Treatment means	19·0	17·2	16·5

Significant difference (*P*=*0·05*)=*1·2.*

This difference occurred in the surface 6 inches of soil as is indicated by the interaction between treatments which was significant at the 0·01 level. Each figure represents the mean of determinations made on two occasions.

	Moisture per cent dry soil.		
Sample depth.	CRD 189 to 9 in.	CRD 189 to 3 in.	Untreated.
0–3 in.	21·1	17·2	16·4
3–6 in.	20·1	17·0	16·2
6–9 in.	17·6	17·4	16·7
9–12 in.	17·4	17·1	16·5

Significant difference (*P*=*0·05*)=*1·61.*

It appeared, however, that the mean weight of unit volume of the deeply treated soil was significantly less (P=0·01) than that for the other two treatments, as follows :

Sample depth.	Apparent density (gm./c.c.). CRD 189 to 9 in.	CRD 189 to 3 in.	Untreated.
0–3 in.	1·25	1·23	1·30
3–6 in.	0·98	1·11	1·16
6–9 in.	1·08	1·17	1·12
9–12 in.	1·18	1·28	1·31
Treatment means	1·12	1·20	1·22

Significant difference (P=0·05) between means=0·03.
Significant difference between treatments at same depth=0·18.

This gave the interesting result that, at field capacity, practically the same amount of water was held in the top foot of the treated and untreated soil, although, as the interaction between treatments and depths shows, the water content of the surface 3 inches of the deeply conditioned soil is significantly higher than that of the other treatments. The high value in the 6-9 in. depth under the 3 in. treatment is unlikely to be a real effect. The figures for moisture content per unit depth of soil have been expressed in inches of water and were determined on one and the same occasion as the figures for apparent density.

Sample depth	Moisture expressed in inches of water. CRD 189 to 9 in.	CRD 189 to 3 in.	Untreated.
0–3 in.	0·76	0·67	0·67
3–6 in.	0·56	0·58	0·59
6–9 in.	0·56	0·63	0·58
9–12 in.	0·62	0·66	0·64
Total content at field capacity ..	2·50	2·54	2·48

Significant difference (P=0·05) between treatments at same depth=0·05.

Since the surface high moisture content is absent from the 3 in. conditioned soil it appears that the surface value of the 9 in. conditioned soil may be related to the structure of the underlying soil. Except for shallow-rooted crops and seedlings it is unlikely that the increased water content of the surface 3 inches of the deeply conditioned soil is of much economic importance, for a series of soil moisture content values determined from soil samples taken during the summer of 1952 (Table I) indicate that the increased content was lost by evaporation over and above the loss which occurred from the other two treatments.

TABLE I.

THE EFFECT OF CONDITIONING WITH CRD 189 TO 3 IN. AND 9 IN. DEPTHS ON THE SOIL MOISTURE CONTENT OF BARE SOIL, 1952.

Treatment.	Sample depth, in.	Water content in inches (on following sampling dates).							
		7 June.	19 June.	10 July.	30 July.	6 Aug.	22 Aug.	1 Sept.	14 Sept.
CRD 189 to 9 in. depth	0–3	0·51	0·30	0·30	0·21	0·48	0·52	0·43	0·32
	3–6	0·37	0·37	0·39	0·37	0·41	0·46	0·41	0·41
	6–12	0·98	0·96	0·92	0·96	1·07	1·11	1·02	0·86
	Total 12 in.	1·86	1·63	1·61	1·54	1·96	2·09	1·86	1·59
CRD 189 to 3 in. depth	0–3	0·54	0·32	0·31	0·22	0·49	0·53	0·45	0·30
	3–6	0·39	0·38	0·40	0·40	0·45	0·52	0·45	0·40
	6–12	1·01	1·00	0·99	1·00	1·06	1·17	1·06	0·92
	Total 12 in.	1·94	1·70	1·70	1·62	2·00	2·22	1·96	1·62
Control	0–3	0·48	0·28	0·28	0·21	0·48	0·56	0·42	0·33
	3–6	0·40	0·37	0·38	0·37	0·47	0·53	0·45	0·40
	6–12	0·97	0·89	1·00	0·97	1·03	1·14	1·02	0·89
	Total 12 in.	1·85	1·54	1·66	1·55	1·98	2·23	1·89	1·62

Structural changes.

After the treatments were begun it was observed that with successive summer rains the conditioned plots retained a loose crumby surface whilst the control plots slowly panned at the surface. The frequent light cultivating done to control the weeds, however, kept the surface pan broken during the summer months, but, during the winter of 1952-53, no cultivation was done and by 20th January, 1953, the effects of rain, frost, and thaw were clearly evident (Fig. 3). The surface of the control plots had completely slaked and the absence of an edge showed the effect of surface panning and run-off. In strong contrast the surface of the conditioned plots showed the same open, crumby condition that was present some three months earlier at the time of the last cultivation, and the presence of an edge illustrates the resistance of the conditioned soil to breakdown and panning. This property of CRD 189 to stabilize soil aggregates has also been confirmed by aggregate analyses.

Discussion.

Hedrick and Mowry (1952) report an increase in water-holding capacity of soil treated with CRD 189 and CRD 186 from laboratory determinations made on equal weights of treated and untreated soil. The present study confirms this finding for CRD 189 but, since it is the amount of water per unit depth of soil, and not the amount per unit weight, which is of significance for plant growth, it is considered that soil moisture contents expressed on the volume basis are far more informative. Since conditioning was found to reduce the weight of unit volume of soil in this experiment, it follows, of course, that the increase in moisture content of a given weight of treated soil compared with an equal weight of untreated soil is not reflected to the same extent in the comparison between equal volumes of treated and untreated soil. However, it must be remembered that, where incorporation of the conditioner with a given depth or volume of soil results in a decrease in apparent density of the soil, an increase in soil depth must occur. This would seem to account for the reduced apparent density of the 9-12 in. depth of soil under the conditioning treatment to 9 in. Thus, in considering the effects of conditioning on the water reservoir of the soil, the increased depth of soil resulting from the conditioning should also be taken into account, and justifies examination of the extent of the difference between total water content at field capacity on the volume basis and on the weight basis. The latter, of course, includes any increase in soil moisture content due to increase in volume of the soil and the water content in inches can be calculated by substituting the apparent density values of the untreated soil for those of the treated soil.

	Total water content at field capacity in inches.		
	CRD 189 to 9 in.	CRD 189 to 3 in.	Untreated.
By weight on 12 in. depth of untreated soil	2·71	2·58	2·48
By volume on 12 in. depth of treated and untreated soil	2·50	2·54	2·48

This clearly shows that the conditioner has resulted in an increase in the water reservoir of the soil although it is an increase achieved by virtue of increasing the volume of the soil. This explains why Hedrick and Mowry are able to claim both improved aeration and water-holding capacity for conditioned soil. The increase in the water reservoir of the soil conditioned to 9 in. is of sufficient magnitude to be of importance to some growing crops provided it is an increase in the amount of available water. The increase given by the 3 in. treatment is probably too small to be of much significance to a crop.

Despite the higher soil moisture content at field capacity of the surface 3 in. of the 9 in. conditioned soil, samplings during the summer season of 1952 showed no persistent differences in moisture content of unit depth of soil between conditioned and untreated soil. A similar finding is reported in a technical note by Berryman (1953). Thus there is no evidence of any reduction in moisture loss by evaporation from the conditioned plots compared with the control plots ; in fact, there appears to be a greater evaporation loss from the soil conditioned to 9 in. owing to the higher water content of the wet surface layer. Hedrick and Mowry found that the rate of evaporation from the surface of equal weights of conditioned and untreated soil held in beakers on a greenhouse bench was less from the conditioned soil. The results of this experiment are hardly conclusive because the apparent density of the soil was equalized by tapping the beakers and treated and untreated soil was exposed to the evaporation treatment at the same moisture content. It appears unlikely from the present work that any soil which responds to conditioning will possess the same apparent density and the same moisture content at field capacity after conditioning as before.

The difference in moisture content values at the surface of the deeply and shallowly conditioned soils is most probably due to a modified structure of the soil immediately below the surface layer of the 9 in. treated soil.

The most interesting feature of this study is the consistently lower soil moisture tension in the deeply conditioned soil compared with the control soil. This effect does not appear to be attributable to differences in water-holding capacity or to evaporation losses as was originally thought by the author, nor can it be entirely accounted for by the slight increase in depth of the conditioned soil, but again is probably related to a modified structure of the soil giving rise to a pore size distribution which permits the release of moisture at lower tensions than occurs in the untreated soil. This, in fact, means that, within the tension range measured, the soil moisture is more readily available in the conditioned soil, and in effect is similar to that of a coarse-textured soil compared with a fine-textured one. The influence of the 3 in. conditioned soil appears to be in the form of a reduced tension gradient through the soil, but with surface drying comparable with that occurring in the untreated soil. The extent that this can modify soil moisture tension must be limited by the shallow depth of the treated soil.

The apparent deterioration in the soil moisture relationships of the 3 in. treated soil, as indicated by the close similarity in tensions to the control during 1953, is possibly due to the fact that walking over the plots as well as continued cultivation has resulted in a deterioration in the structural arrangement of aggregates so that the pore size distribution of this soil is approaching that of the untreated soil. If this is occurring, then it will also be true of the deeply treated plots, and some evidence of this has been provided by soil samples, but any effect on soil moisture tension has been masked by the influence of the much greater depth of conditioned soil which has not been disturbed.

Only one clear indication of a difference in rate of rainfall penetration into the treated and untreated soils was provided by the tensiometer data. On 8th and 9th July, 1953, 0·5 in. rain fell which reduced the tensions of the treated soil, but it was not until two further rainfalls had occurred, 0·36 in. on 11th July and 0·42 in. on 12th July, that the tension of the untreated soil fell from 60 cm. Hg on 13th July, that is four days after the first reduction in tension in the conditioned soil. From the moisture content data of 1952 it is unlikely that the control plots were substantially drier than the treated plots, so that this lag in rain penetration on the untreated soil indicates that the permeability of the surface layer of soil is low compared with that of the conditioned soil.

The effectiveness of CRD 189 in stabilizing the soil aggregates of the fine sandy loam used in this study is beyond dispute (Fig. 3), and the persistence of this stabilization has continued now for over 18 months.

This study, which has been carried out on fallow soil, would not be complete without determining the effects of the conditioned soil on the growth and development of plants. In the autumn of 1953 all the plots were planted with runners of Royal Sovereign strawberry which were selected for similarity in size and weight. The strawberry is known to be very responsive to soil moisture supply, the highest production of fruit being obtained when soil moisture tension is maintained at a relatively low level. Subsequent yield figures should therefore indicate in due course whether the effect of deep or shallow incorporation of a soil conditioner on soil moisture tension and on the soil moisture reservoir is of any practical importance.

Acknowledgements.

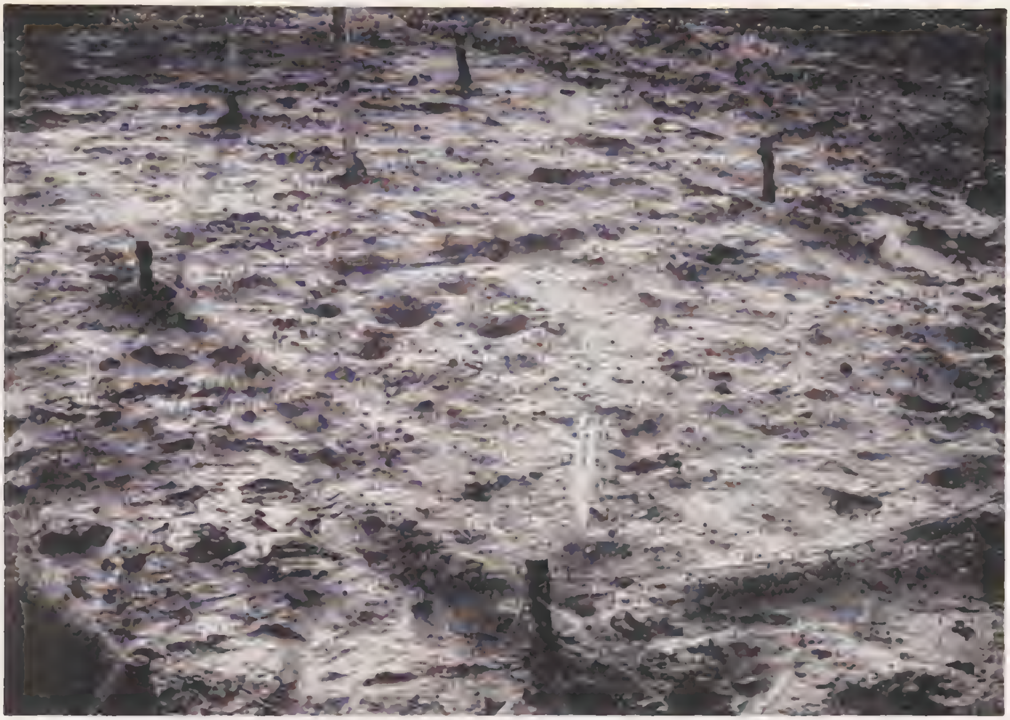
The writer is indebted to Dr. W. S. Rogers for guidance and valuable suggestions, and to Messrs. Monsanto Chemicals for supplies of CRD 189.

Summary.

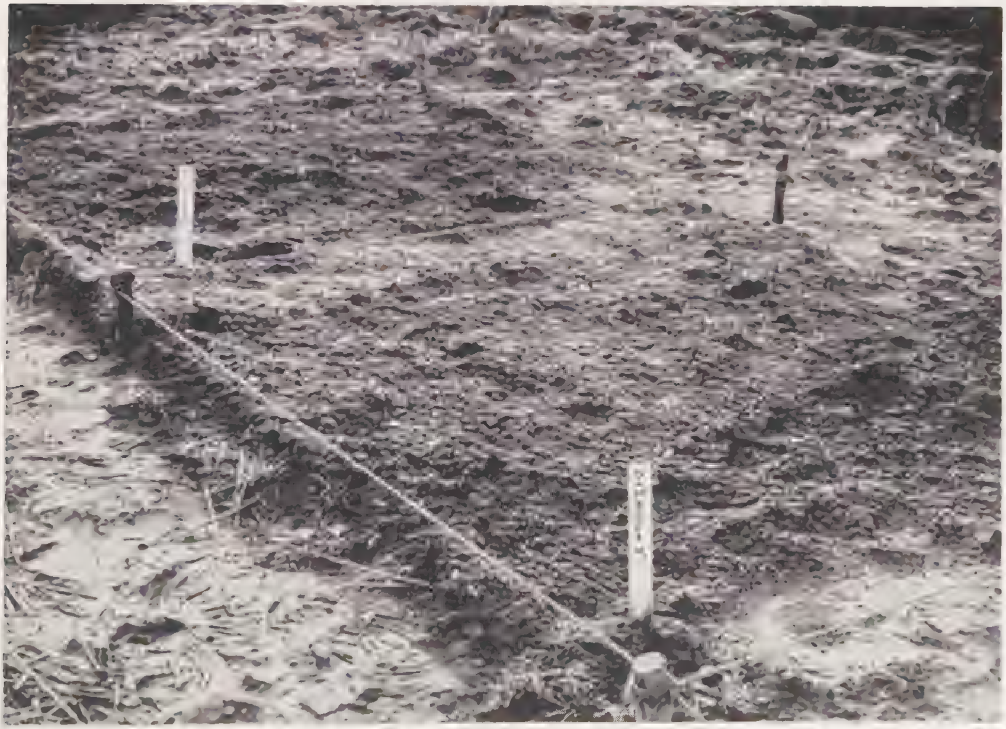
The effects of the incorporation of a soil conditioner, CRD 189, in a fine sandy loam to depths of 3 in. and 9 in. on soil moisture tension, soil moisture content, and soil structure are reported.

The rate of soil moisture tension increase associated with soil moisture loss was found to be less for conditioned than for untreated soil. Thus the soil moisture tension of conditioned soil was generally lower and the water more readily available than that in untreated soil. This effect is thought to be due to an improved structural arrangement of stable soil aggregates brought about by incorporation of the conditioner.

There appeared to be an increase in the water reservoir of the treated soil due to an increase in the soil volume, but there was no evidence either of an effective increase in moisture in equal depths of treated and untreated soil or that evaporation losses from the conditioned soil were reduced.



(a) Control plots. Note surface panning.



(b) Conditioned plots. Note good surface tilth.

FIG. 3.

Effect of weathering on surface structure of soil.

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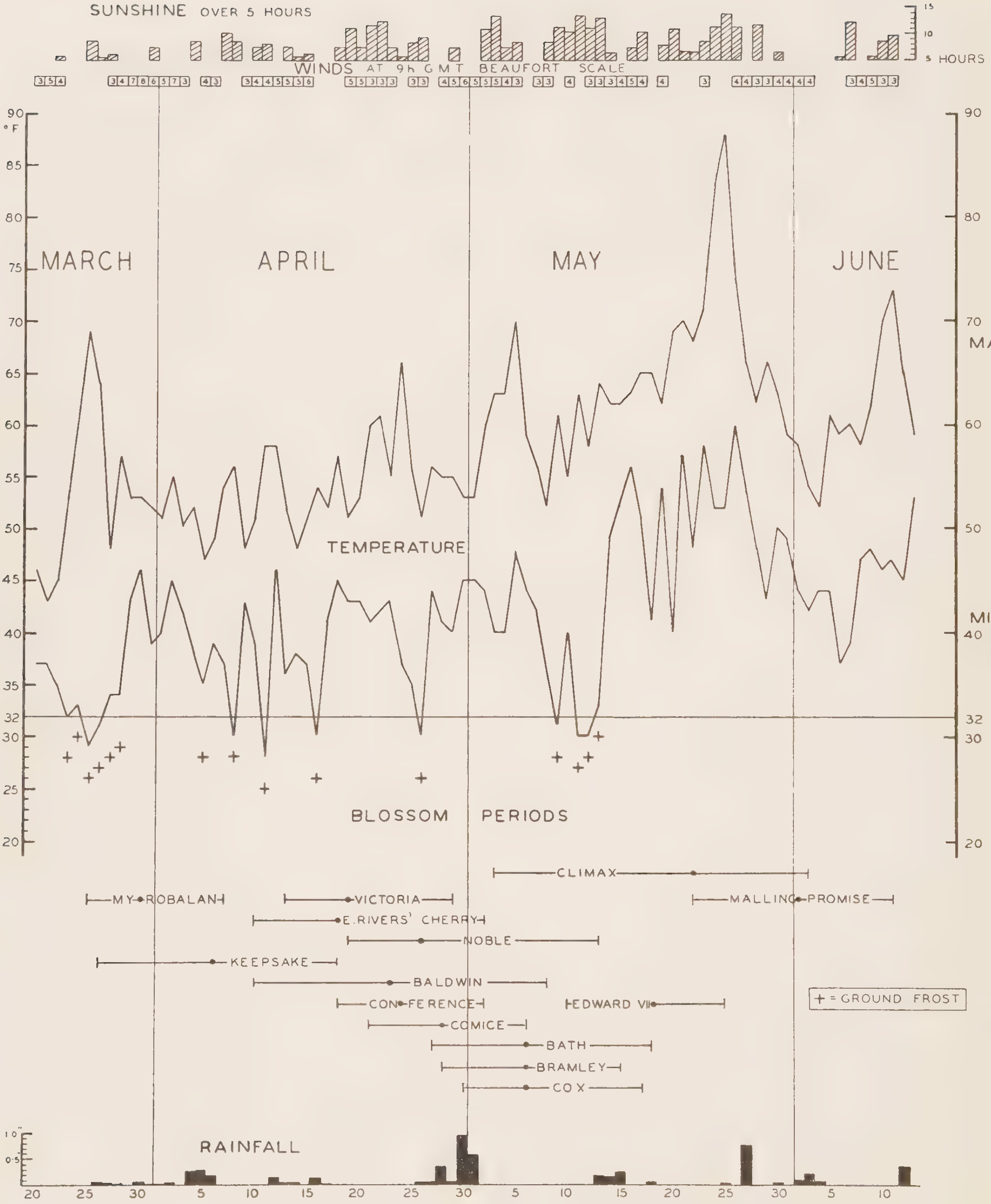

FIG. 1.

Diagram showing the weather recorded during the blossoming season in 1953.

WEATHER CONDITIONS DURING 1953

By A. P. PRESTON and G. F. TROWELL

The past year has been comparatively dry with the total rainfall 5·16 inches below the 35 years' average. April, May, July, and September all had rainfall above the average, September being the wettest month ; March and December were unusually dry. The heaviest fall on any one day occurred on 30th April when 0·91 inches were recorded. Snow was recorded 12 times during the first 3 months of the year and the ground in the neighbourhood of the station was snow-covered on 8 days. No snow was recorded during the latter part of the year.

Ground frosts were fewer than usual, 68 compared with 95 in 1952 and 78 in 1951, the largest number occurring in March. There were no serious late spring frosts, although twice during the second week of May the screen temperature fell to 30° F. and the grass temperature to 27° F. once and to 28° F. twice (Fig. 1). Cold northerly winds were recorded during the first two weeks of May while the apple was in blossom. The latter months of the year were unusually mild.

Sunshine was a little above the average, May being the sunniest month. The highest temperature, 88° F., was recorded on 25th May and again on 12th August.

Local thunder was recorded 4 times during June, July, and August, and 3 thunderstorms occurred over the station during July.

The station was inspected by officers of the Meteorological Office during the year and was reported on satisfactorily.

Newlands Farm, Throwley.

Rainfall at this sub-station was 4·69 inches higher than that for East Malling ; the sunshine was also higher by 40 hours. As in previous years the mean maximum temperatures were lower than those at East Malling while the mean minimum temperatures tended to be higher.

In past years there has been very little difference in the number of ground frosts at the two stations but this year 21 more were recorded at Newlands Farm than at East Malling.

Acknowledgement.

Mr. J. Cronk (by courtesy of Mr. T. Neame) was responsible for records at Newlands Farm and his co-operation is gratefully acknowledged.

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1953.

EAST MALLING.

Month.	TEMPERATURE IN SCREEN.					NUMBER OF GROUND FROSTS.	RAINFALL.			SUNSHINE.			SOIL TEMPERATURES.			
	Mean maximum.	Mean minimum.	Highest.	Lowest.	Mean.		Total in inches.	Heaviest fall in a day.	35* years' average.	Total hours.	Average per day.	25 years' average.	4 inches.	8 inches.	2 feet.	4 feet.
JANUARY	41	32	56	23	36	15	1·09	0·39	1·96	27·9	0·9	47	35·4	35·9	37·9	40·4
FEBRUARY	44	33	56	20	38	12	1·22	0·35	1·85	59·1	2·1	68	36·6	37·1	39·0	40·4
MARCH ..	49	32	69	23	40	21	0·21	0·07	2·01	126·1	4·1	123	39·7	40·1	41·9	42·3
APRIL ..	53	39	66	28	46	5	2·44	0·91	1·65	172·4	5·7	152	46·3	45·8	46·5	45·3
MAY ..	64	45	88	30	54	4	1·90	0·74	1·67	251·1	8·1	200	56·7	55·3	54·4	50·7
JUNE ..	66	49	79	37	57	0	1·50	0·36	2·04	171·4	5·7	222	59·4	58·4	57·8	54·9
JULY ..	69	51	79	45	60	0	2·83	0·42	2·19	206·9	6·7	208	62·3	61·8	62·0	58·9
AUGUST ..	71	51	88	41	61	0	1·82	0·46	2·19	239·6	7·7	194	62·2	62·0	62·5	60·0
SEPTEMBER	66	46	75	37	56	0	3·10	0·79	1·98	193·6	6·5	147	56·0	56·5	58·7	58·2
OCTOBER	58	43	69	31	50	2	2·76	0·73	3·11	76·8	2·5	105	50·6	51·2	53·7	54·8
NOVEMBER	52	40	59	29	46	6	1·33	0·68	2·79	50·7	1·7	55	45·2	45·9	48·3	50·5
DECEMBER	49	40	61	28	44	3	0·74	0·24	2·66	36·0	1·2	42	43·6	44·6	46·9	48·8
TOTALS ..						68	20·94		26·10	1611·6		1563				

SUB-STATION, NEWLANDS FARM, THROWLEY.

Month.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Mean.	NUMBER OF GROUND FROSTS.	Total in inches.	Heaviest fall in a day.	35* years' average.	Total hours.	Average per day.	25 years' average.	4 inches.	8 inches.	2 feet.	4 feet.
JANUARY	40	32	54	26	36	17	1·38	0·37		32·9	1·1		35·7	36·1	38·3	41·5
FEBRUARY	42	32	51	24	37	17	1·63	0·43		62·7	2·2		36·5	37·1	38·8	40·9
MARCH ..	48	33	68	25	40	20	0·26	0·13		127·7	4·1		39·0	39·8	42·6	42·1
APRIL ..	52	39	64	33	45	12	1·78	0·76		178·4	5·9		45·0	45·2	45·3	44·3
MAY ..	61	45	83	35	53	7	1·93	0·82		250·8	8·1		54·4	53·9	52·2	48·4
JUNE ..	63	49	75	41	56	0	2·71	0·78		178·3	5·9		57·4	57·2	56·2	52·6
JULY ..	66	52	77	48	59	0	3·52	0·69		198·5	6·4		61·1	60·8	60·2	56·3
AUGUST ..	69	53	84	45	61	0	2·17	0·61		241·7	7·8		61·3	61·5	61·6	58·4
SEPTEMBER	64	49	73	43	56	0	4·51	0·94		190·9	6·4		54·3	57·2	58·7	57·8
OCTOBER	56	46	67	38	51	2	2·87	0·61		96·4	3·1		52·1	52·8	54·6	55·4
NOVEMBER	51	42	57	35	46	5	1·96	0·72		50·6	1·7		46·0	46·9	49·4	51·8
DECEMBER	48	40	58	33	44	9	0·91	0·23		42·9	1·4		44·8	45·7	48·0	49·8
TOTALS ..						89	25·63			1651·8						

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* Weighted averages for the 35-year period 1881–1915, as used in the Monthly Weather Report of the Meteorological Office.

STATISTICS

FORECASTING THE TIME OF BLOSSOMING IN APPLE TREES FROM TEMPERATURE RECORDS

By S. C. PEARCE and A. P. PRESTON

The environmental factors influencing the development of periodic processes in plant growth interact with such complexity that they impose limits on the study of one factor alone. Nevertheless, of the many climatic elements influencing the vegetative and reproductive phases of growth, temperature is of paramount importance.

This paper describes attempts to relate temperature to the time of blossoming of apple trees so that a reliable method of forecasting may be evolved. Time of blossoming varies greatly from year to year within a variety. Thus, defining full blossoming as the time at which 50 per cent of blossoms are open, for Bramley's Seedling at East Malling it lies anywhere between 12th April and 22nd May and even these limits may be exceeded in one season in twenty. Considerable benefit would arise, therefore, from a more precise forecast of time of blossoming especially when associated with long-range weather forecasting. Such a forecast would facilitate protective measures against late spring frosts, also recommendations as to the time of spraying in relation to the stages of development of pest and disease organisms. Apiarists, too, would find a forecast useful in gauging the spring management of their colonies when they are undertaking the supply of hive bees on contract to growers for fruit tree pollination.

Some previous work.

A critical study of meteorological data in relation to the blossoming of apple and peach at three centres in the U.S.A. was made by Bradford (1922) who showed the inaccuracy of Reaumer's hypothesis, later modified by other workers, that a given summation of heat is required to cause blossoming. The hypothesis that a ' threshold value ' and temperature sums are important in physiological processes has been fully discussed by Bos (1906).

More recently, however, Herbst and Weger (1940) in Western Germany determined a ' threshold ' temperature of 6° C. (43° F.) for pears, below which flower development did not proceed, furthermore that the effect of temperature above this figure, calculated from 1st January as zero day, is additive. Brown (1943), also working with pears, at Merton near London, lacked the data to calculate in degree hours but, using the five half-monthly periods up to full blossom, he found that in an early season the mean temperature during each month exceeded 43° F. while, in a late one, this temperature was not exceeded until the first half of April.

Maclagan (1933), working at Edinburgh, recognized that the use of temperature summation above an arbitrary datum line as an expression of effective heat was unsatisfactory. Working with different species of *Cytissus*, *Rhododendron* and *Syringa*, he compared temperature and blossoming records in an attempt to find a consistent correlation between the temperature at certain periods during the year and time of flowering. Over a ten-year period a consistent response was found to the temperature during distal and proximal or proximal and intermediate weather belts ; he referred these narrow belts of time, often remote from the time of flowering, to periods of activity in gamete formation.

Accumulated day degrees.

Several workers have used accumulated day degrees above 42° F., which is a measure of the period spent above that temperature, two hours at 43° F. counting for as much as 44° F. for one hour. Strictly they should be evaluated from hourly values, but in this investigation daily maximum and minimum temperatures were used as in the Agricultural Crop Weather Scheme (Air Ministry, 1928).

Work at East Malling.

The authors have used the East Malling data for accumulated day degrees above 42° F., evaluated in the manner just described, in an attempt to establish a correlation with time of blossoming data for two apple varieties. The main series was of Bramley's Seedling on M.I using data from 1936 to 1945, the subsidiary series was of Worcester Pearmain on M.I using data from 1919 to 1935.† The second series was used as a means of confirming results obtained from the first. Obviously, if the time of blossoming is correlated with conditions in a sufficient number of periods, something will appear significant by chance, so supporting evidence such as that given by the second series was sought before deciding that a particular correlation was genuine.

Little success was achieved when the data were analysed along the lines Brown (*loc. cit.*) had used for pear varieties, that is dividing each month from December to the time of blossoming into two parts and finding the mean temperature for each. Maclagan's work, however, indicated a reasonable line of approach and a statistical investigation into the relationship between accumulated day degrees and time of blossoming for the two varieties was carried out searching for possible distal, intermediate, and proximal periods. The work was done using partial regression coefficients. A period having been found for which there appeared to be an effect of temperature on subsequent blossoming, a double regression analysis was worked out for the effect upon blossoming time of temperatures in that period and in a neighbouring one. In this way it was found both if the conditions in the first period were really relevant and if the period could usefully be extended to include its neighbour as well.

Search for the proximal period.

For Bramley's Seedling this was found to begin abruptly about 15th January and to continue till about 15th April. Day degrees accumulated from the middle of January to the middle of March all appeared to have a similar effect on time of blossoming, but from about 16th March temperature had an ever-diminishing effect ; this confirms observations by Brown (1940) also on apples. The best forecasting variate for the period, y, was taken to be

$$y = (\text{Accumulated day degrees from 15th January* to 15th March})$$
$$+\tfrac{2}{3}\,(\text{Accumulated day degrees from 16th March to 31st March})$$
$$+\tfrac{1}{3}\,(\text{Accumulated day degrees from 1st April to 15th April})$$

For Worcester Pearmain the period appeared to start about a fortnight later and to end less gradually, but the data provided the general confirmation sought.

Search for the intermediate period.

The proximal period having been found, efforts were made by means of double regression methods on y and on conditions in various periods during the last four months of the preceding years to find an intermediate period, but without success.

Search for the distal period.

Examination of the main series of data showed that there was a significant correlation between the accumulated day degrees in June and the date of full blossom in the following year, though the relation was, rather unexpectedly, that a hot June delayed blossoming instead of bringing it forward. Examination of the two periods, 1st to 15th June and 16th to 30th June, by the method of partial regression suggested that it was immaterial in which half of the month the warmth occurred. The same method was then used to consider the periods 17th to 31st May and 1st to 15th July, but there was no suggestion that warmth outside the month of June affected time of blossoming. The subsidiary set of data confirmed the effect of June temperatures, though with Worcester Pearmain the effect appeared to be less marked. A second forecasting variate had thus been found, namely x, equal to the accumulated day degrees above 42° F. in June.

Subsequent experience, 1946-53.

On the basis of the above conclusions, two formulae were worked out, one based on y alone and the other on both x and y, as follows :

$$55{\cdot}6 - 0{\cdot}1178y \quad \ldots \quad \text{A}$$
$$0{\cdot}1297x - 0{\cdot}0920y - 15{\cdot}7 \quad \ldots \quad \text{B}$$

Formula A was included on account of the difficulty the authors had in believing that June weather would really affect time of blossoming in the way indicated in Formula B and their consequent wish to test the matter in practice. The formulae give the number of days from the end of March to full blossom, for Bramley's Seedling on M.I at East Malling. Thus, if a formula on being worked out gives a value of 24 this would indicate 24th April as the date of full blossom, just as 35 would indicate 5th May.

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† These trees were very young in 1919 and an adjustment by regression had to be made to allow for increasing age. The data actually continued after 1935, but were ignored after that year so as to maintain independence of the main series.

* An asterisk, here and subsequently, indicates ' one day later in leap year '.

TABLE I.

ESTIMATED AND ACTUAL TIMES OF FULL BLOSSOM 1946-1953.

	1946.	1947.	1948.	1949.	1950.	1951.	1952.	1953.
Formula A	31	45	23	30	26	42	37	39
Formula B	34	32	32	27	23	51	29	39
Mean $\frac{1}{2}$ (A+B) ..	$32\frac{1}{2}$	$38\frac{1}{2}$	$27\frac{1}{2}$	$28\frac{1}{2}$	$24\frac{1}{2}$	$46\frac{1}{2}$	33	39
Actual	29	38	25	25	35	48	30	36

Results over the period are set out in Table I. In 1950 at about the time of blossoming as forecast from the formulae there was a cold spell. This affected the forecast (Table I) but otherwise the agreement is encouraging, though it should be noted that a better estimate than either A or B is given by their mean, suggesting that the effect of the distal period, though real, has been overestimated.

Revised formulae.

In the light of this information a series of formulae was worked out using data for Bramley's Seedling on M.I for the whole period for which observations are available, namely, 1936-53. They are given below, the value of y for occasions other than the last being that part of y, as defined above, accumulated up to the preceding midnight.

1st July .. .. $0\cdot1023x-20\cdot3$
1st February* .. .. $0\cdot1106x-0\cdot1756y-20\cdot9$
15th February* .. .. $0\cdot1311x-0\cdot1710y-25\cdot8$
1st March .. .. $0\cdot1239x-0\cdot1478y-19\cdot3$
16th March .. .. $0\cdot1047x-0\cdot1122y-7\cdot9$
1st April .. .. $0\cdot0882x-0\cdot0976y+3\cdot9$
16th April .. .. $0\cdot0822x-0\cdot0983y+9\cdot9$

Table II sets out the dates of blossoming for this period together with the estimates given by these formulae, and it can be seen that forecasting on 16th March or even on 1st March, with occasional exceptions like 1950, agreement is quite good, though it should be borne in mind that somewhat better

TABLE II.

ACTUAL AND ESTIMATED DATES OF BLOSSOMING USING REVISED FORMULAE.

Year.	1st July.	1st Feb.*	15th Feb.*	1st March.	16th March.	1st April	16th April	Actual.
1936	35	35	40	40	40	36	38	39
1937	36	34	31	30	34	36	35	35
1938	30	24	23	24	19	16	16	16
1939	34	29	24	26	26	30	28	34
1940	27	31	34	33	33	33	34	36
1941	39	44	45	45	43	44	44	49
1942	34	38	43	46	44	43	42	40
1943	30	23	20	21	22	20	22	21
1944	30	24	25	30	33	35	36	31
1945	28	32	26	20	20	19	18	15
1946	35	38	32	32	36	34	33	29
1947	25	27	30	34	36	36	37	38
1948	38	37	33	36	30	29	29	25
1949	29	27	27	22	27	29	28	25
1950	29	33	30	25	24	24	24	35
1951	41	41	45	46	46	46	47	48
1952	27	30	33	35	31	32	32	30
1953	34	34	39	36	37	38	38	36

agreement is to be expected over the years from which the formulae were derived than over past or future periods. Also it will be noted that the winter estimates, made subject to normal spring weather, were often close enough to be of value. In three years, 1939, 1941, and 1950, records showed that abnormally cold conditions occurred during April and early May, mainly on account of north-easterly airstreams, and in one year, 1950, considerable snowfall was recorded. These conditions occurred at the onset of the blossoming period and doubtless accounted for the discrepancies between forecast and actual date by retarding the normal opening of blossom.

Discussion.

These formulae provide a means of forecasting the time of blossoming which may well be useful. The picture given is that of a tree passing through successive stages of development, in some of which it is more susceptible to heat than in others. If such formulae were available for a range of apple varieties it would be possible to judge how far a tendency for two varieties to blossom together was inherent and how far coincidental. Thus, the two varieties used in this investigation usually blossom at about the same time, but if the indication is correct that Worcester Pearmain is less affected by January warmth than is Bramley's Seedling but more by warmth after the end of March, it is possible for there to be seasons in which these two varieties are out of step, as does in fact sometimes happen.

The formulae may be found particularly useful in forecasting whether or not the blossom season for apples is likely to be unusually early or late. By the middle of March it was possible to forecast the early blossoming years of 1938 and 1945 and considerably earlier the late blossoming years of 1936, 1941, 1942, and 1951 (Table II).

No advantage was found by supplementing the number of accumulated day degrees during the proximal period with either sunshine values or the rainfall values for the previous June.

The small error of ±3 or 4 days between the forecasted and actual dates of full blossom (Table II) is of little practical importance, because the estimate of time of full blossom itself is likely to be affected by the personal factor. Furthermore, the trees may well have had considerable amounts of blossom open for several days before they were judged to have reached the ' full blossom ' stage.

There are several ways in which the estimates might be improved :

(1) By discovering and taking into account other factors that affect time of blossoming. This point is too obvious to require further comment. The chief need is for a means of assessing well in advance the effect of weather conditions just before blossoming.

(2) By improving the method of calculating accumulated day degrees. Herbst and Weger (*loc. cit.*) have improved upon the standard German method which in its turn appears more accurate than the one used here.

(3) By shifting the distal period to allow for the state of advancement of the previous growing season and by defining it more closely. Attempts along these lines have, up to the present, proved unavailing.

(4) By the use of long-range weather forecasts when available, although in this respect it seems doubtful whether a high degree of accuracy can be hoped for in an island country such as Britain.

Acknowledgements.

The authors wish to thank the Director of the Commonwealth Bureau of Horticulture and Plantation Crops for a translation of the paper by Herbst and Weger, also Miss Eleanor C. Thompson (now Mrs. G. M. Jolly) who made most of the time of blossom records. They are also indebted to Miss Margaret J. Hall for working out the revised formulae.

Summary.

Some previous work on the relationship between air temperature and time of blossoming is surveyed. An attempt is made to forecast the time of blossoming (50 per cent of blossoms open) of trees of Bramley's Seedling and Worcester Pearmain, both on M.I, using accumulated day degrees. Distal and proximal periods were found where temperature affected the time of full blossom ; an intermediate period was sought but not found. Hot weather during the distal period (June) delayed blossoming the following year. For Bramley's Seedling the proximal period began abruptly about 15th January and continued until 15th April, but from 16th March temperature had a diminishing effect upon time of blossoming. With Worcester Pearmain this period began a fortnight later and ended less gradually. The data confirmed those for Bramley's Seedling.

Formulae are presented for forecasting the time of blossoming of Bramley's Seedling, and forecasted and actual dates are given over an 18-year period. The results are discussed and possible improvements in the technique of forecasting outlined.

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STUDIES IN THE MEASUREMENT OF APPLE TREES

II. THE HEIGHT AT WHICH TRUNK GIRTHS SHOULD BE MEASURED

By S. C. PEARCE and G. E. DAVIES

In the first paper of this series (Pearce, 1952) attention was directed to the problem of estimating the weight of a tree from the trunk girth. Taking the logarithm of the weight to be w and the logarithm of the girth to be g, a study was made of the relationship, $w=a+bg$, where a and b are constants for trees similarly treated.

In this paper a similar study will be presented in which g, the logarithm of a girth low in the trunk, is used to estimate h, i, j, etc., corresponding values measured higher up. The statistical methods will be those of the former paper, and will consist of a series of three related tests, (i) a preliminary test to make sure that the data fulfil the conditions required by the later tests of showing similar variabilities and correlation coefficients in all treatments, (ii) a test that b is unaffected by treatments, and (iii) assuming b to be invariant, a test that a is also.

Material and records.

Use was made of data from seven trials, which were numbered so as to continue the series of the previous paper, namely :

R4. Thirty-two trees of Cox's Orange Pippin, 24 years old, eight on each of the rootstocks M.I, M.II, M.IX and M.XIII. These were selected from the same experiment as Trial *R3* in the former paper. *Records*.—Trunk girth nine inches above the graft union (g) and just below the crotch (k). For reasons to be explained later, not all these trees were used.

R5. Ninety-six trees of Lane's Prince Albert, 23 years old, eight on each of the rootstocks M.I to M.XVI, omitting M.III, M.VIII, M.XI and M.XIV. *Records*.—Trunk girth nine (g), fifteen (h) and twenty (j) inches above the graft union. In some instances it was necessary to lower the topmost girth by one inch in order to avoid the crotch.

R6. Forty-nine trees of Worcester Pearmain, 23 years old, seven on each of the seven rootstocks M.I, M.II, M.V, M.VI, M.IX, M.X and M.XIII. *Records*.—Trunk girth at nine inches above the graft union (g) and just below the crotch (k).

P1. Thirty-two trees of James Grieve, 22 years old, on mixed Paradise rootstocks, divided equally as to number between the pruning treatments (i) unpruned for about the first 14 years, (ii) long spur pruned, (iii) short spur pruned, and (iv) regulated. This was Trial *P* of the former paper. *Records*.—A lower girth mark had been chosen when the trees were about nine years old to show the minimum girth at that time (g'). An upper girth had been chosen at the same time to come just below the crotch (k').

P2. Thirty-two similar trees of Beauty of Bath, 22 years old, similarly divided among the same four treatments. *Records*.—As in Trial *P1*.

M3. Forty-two trees of Cox's Orange Pippin on M.I, 17 years old. Throughout their lives half these trees had received more potash than the others, and this had built up a large difference in tree size between the two groups. There were also other manurial differences that had had comparatively little effect and these were ignored. *Records*.—Trunk girths nine and eighteen inches above the graft union (g and i respectively).

M4. Sixty trees of Beauty of Bath on M.IX, 19 years old, similarly divided into two halves. *Records*.—Trunk girths at nine (g), eighteen (i) and twenty-one (j) inches above the graft union.

In all these trees the crotch was about 20 to 24 inches above the union.

Preliminary examination of data.

In Trial *R4* one of the trees on M.IX was rejected because of a canker on the lower girth mark. Results from the other trees were erratic but this was apparently due to the cutting out of damaged branches from some of the trees and this had affected the development of the tops of the trunks. Certain trees were accordingly omitted, leaving three on M.I, eight on M.II, five on M.IX and six on M.XIII. The results to be presented refer only to these undamaged trees.

In order to satisfy the preliminary test for suitability of data, it was necessary to reject rootstock M.X from Trial *R6*. Strictly the whole of Trial *M4* should have been rejected also, the two treatments not being comparable on account of the generally higher variation among trees receiving low potash. However, with so many trees to a treatment the preliminary test was very sensitive and had detected a difference quite small in itself ; so the main tests were carried out, the intention being to accept the results with some reserve unless they were very clear-cut. Fortunately, they proved to be so.

The figures in the middle column of Table I are the correlation coefficients between girths at different levels. They are all very high except those for Trial *M4*, the exception possibly arising from the irregular tops of trunks found with rootstock M.IX, trees on which tend to have spreading branches.

Results.

For no trial did the value of b depend upon the treatments, whether of rootstocks, pruning or manuring. These values also are shown in Table I, in the last column.

TABLE I.

CORRELATION COEFFICIENTS BETWEEN GIRTHS AT DIFFERENT LEVELS AND ALSO REGRESSION COEFFICIENT OF UPPER UPON LOWER. (ALL GIRTHS IN LOGARITHMIC TRANSFORMATION.)

Trial.	Girths.	Correlation.	Regression.
R4	g, k	+0·989	+0·985
R5	g, h	+0·992	+1·022
	g, j	+0·978	+1·032
R6	g, k	+0·976	+1·016
P1	g', k'	+0·993	+0·980
P2	g', k'	+0·998	+1·010
M3	g, i	+0·989	+1·028
M4	g, i	+0·927	+1·045
	g, j	+0·909	+1·007

For the pruning and manurial trials there was no suggestion that the treatments affected the value of a. For the rootstock trials the differences in a were plainly significant ($P=0\cdot05$ for *R4*, $P=0\cdot001$ for *R5*) for Trials *R4* and *R5* and approached significance ($P=0\cdot05$) for *R6*. The results are set out in Table II, which shows (i) for each trial the relative values of upper girths for standard values of the lower girth, M.I being taken as 100·0, (ii) some figures for branch angle for certain trees of Lane's Prince Albert taken from the same experiment as that from which the trees of Trial *R5* were selected, and (iii) figures representing relative weights of tree for a standard lower girth, obtained by adding the results set out for Trials *R1* and *R2* in Table I of the previous paper of this series. It will be seen that stocks M.II, M.V, M.VI, M.X and M.XV, which were low in respect of (iii) were mostly low in respect of (i) also. Stocks M.IX, M.XII, M.XIII and M.XVI, which were high in respect of (iii) tended to be high in respect of (i) also ; but it should be noted that M.XII, which has an upright habit, was not as high in (i) as might have been expected, while M.IX, which gives a spreading tree, was especially high. Study of these points by methods of correlation, both ordinary and partial, showed that there are quite strong grounds for thinking that the trunk shape depends partly upon the tendency of a rootstock to give a large or small head in relation to its trunk and partly upon the angle of the branches.

Discussion.

It appears from these results that the particular differences in pruning described and in the amount of potassium applied did not affect the *shape of the trunk* as determined by the coefficients a and b, although these differences in treatment markedly affected growth and cropping. Nor were there large differences in variability at different heights, so the choice of level must be made on other grounds. Since in the earlier investigation trouble was found with girths nine inches above the graft union on account of swellings with dwarfing rootstocks, and since in this investigation it was found that, when branches are spreading or damaged, upper girths tend to be irregular and not very highly correlated with lower girths, it would seem better to raise the standard girth mark but not by too much. For bush trees such as these, twelve inches above the union would appear to be a reasonable level.

TABLE II.

TABLE SHOWING (i) UPPER GIRTH FOR A STANDARD LOWER GIRTH, (ii) ANGLE OF BRANCHES TO THE VERTICAL, AND (iii) TREE WEIGHT FOR A STANDARD LOWER GIRTH.

Rootstock.	Value of (i).				(ii)	(iii)
	R4.	R5 (*h*).	R5 (*j*).	R6.		
M.I	100·0	100·0	100·0	100·0	43°	200
M.II	100·1	101·1	98·8	101·6	45°	198
M.IV		99·9	100·6			208
M.V		99·9	99·9	101·0		192
M.VI		99·7	98·9	100·1		194
M.VII		101·3	101·5		45°	203
M.IX	101·1	104·6	109·6	105·5	67°	230
M.X		99·3	98·0		46°	196
M.XII		100·3	100·4		39°	227
M.XIII	100·9	101·3	102·4	101·3	46°	230
M.XV		100·6	100·3		45°	195
M.XVI		100·8	102·7		41°	242

For rootstock trials it appears that the trunk taper is likely to depend, at least in part, upon the rootstock, and different results will be obtained according to the level at which girth is measured. Thus, in Table II, for the same lower girth there are differences in upper girth of up to 10 per cent, corresponding to differences of 25 per cent in the estimates that would be made of tree weight. Since, however, the taper is itself an indication, albeit an imperfect one, of the tendency for some rootstocks to give a heavy tree in relation to the trunk, a tendency that has to be measured before girths can be used to estimate tree weight in a rootstock trial, it would appear best to take a standard girth at twelve inches, and one or two higher ones below the crotch. The highest may well be so irregular on account of the branches as to show very little ; but at least one of the supplementary girths may tell consistently a different story from the standard one, and the differences should indicate which are the stocks that give trees large in relation to the girth. Great caution would be needed if the rootstocks caused branch angles to vary a lot, but usually this does not happen.

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Summary.

A study is made of the shapes of trunks of bush apple trees in a range of experiments. It appears that differences in growth brought about by pruning and potassic manuring do not affect the shape, but rootstock does, the differential taper between stocks depending partly upon the tendency of the stock to produce a large or small head in relation to trunk and partly upon the angle of the branches. It is recommended that girth should ordinarily be measured twelve inches above the graft union, with additional higher girths near the crotch in the case of rootstock trials.

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PLANT PHYSIOLOGY

PROGRESS IN THE STUDY OF ROOTSTOCK-SCION INTERACTION

By M. C. VYVYAN and D. H. MAGGS

Domestic varieties of apples are normally multiplied asexually by bud- or stem-grafting on to rootstocks, which may be either seedlings or, more commonly, vegetatively propagated clones. The varieties used as scion and rootstock have each their own natural habits and rates of growth, and, when combined to form a composite tree, the one influences the behaviour of the other. Some workers have reported a predominant effect of the scion (e.g. Tukey and Brase, 1933 ; Swarbrick and Roberts, 1927) and consider that this may impose uniformity in performance upon trees worked on a batch of mixed seedling rootstocks. At East Malling the stock has been found to be predominant (Hatton, 1923), and in Britain and many European countries the use of clonal rootstocks has become the standard practice because of the uniformity and control of tree behaviour it confers. By using a suitable rootstock, the size of the mature tree and the time it comes into commercial bearing can be pre-determined to suit the grower's requirements (Preston, 1954 ; Spinks, 1952). The evidence upon which the effects of a particular rootstock are predicted must at present be based upon experiments extending over many years ; it would be an advantage if, firstly, performance could be foretold more quickly, and, secondly, if more were known about the fundamental principles controlling the mutual effects of scion and rootstock.

Historical background.

The physiological investigations into scion/rootstock relations, started by Knight at East Malling in 1920, were directed mainly towards these two objectives ; his search for ' labels ' that would foretell the performance of new stocks proved unrewarding. He measured transpiration (Knight, 1925) and found it remarkably alike in all stocks, while, although differences in water conduction of the stems were found (Knight, 1927), these were not related to the vigour of the rootstocks. The anatomical approach to this objective proved more fruitful (Beakbane, 1941 ; Beakbane and Thompson, 1939 and 1947), and has shown that the histology and anatomy of the root provide good indication of the influence of a given clone when used as a rootstock.

Long-term physiological investigations into the mechanism of the influence of scion and rootstock on tree size and shape developed mainly as extensions of pomological studies already in progress. For special work small batches of trees were dug up, and the weights of various parts determined (Hatton, Grubb and Amos, 1924). Much of this work was done in the dormant season when measurement could be spread over several weeks. To meet the need for more detailed study, investigations were started on the lines of the quantitative analysis exemplified by Gregory (1918), Blackman (1919), and Briggs, Kidd and West (1920). The method consisted in planting a series of trees, and then lifting samples at intervals throughout the year and determining the weights of the various parts—leaves, branches, trunks, roots, etc.

A start was made in 1929 (Vyvyan, 1931 and 1934) with the simplest material available, viz. unworked rooted shoots from the stoolbed of the rootstock clone M.XIII. The various investigations showed that the ratios between the weights of certain parts of the tree change with increasing size, while those between other parts remain remarkably constant. Thus, other factors being equal, the proportion of fine roots to coarse is lower in large root systems than in small (Amos, Hatton, Hoblyn and Knight, 1930 ; Knight and Hoblyn, 1934). Again, the ratio of branch weight to trunk weight is larger in large trees than in small (Hatton, 1935). Where a ratio thus varies with size, a rootstock or a scion may affect it directly and also indirectly by influencing the size of the composite tree, and this has to be taken into account when examining the apparent effects of scion or rootstock.

The stem/root ratio, on the other hand, is remarkably constant within any one scion/rootstock combination, and is more or less independent of tree size or age (Hatton, Grubb and Amos, 1924 ; Rogers and Vyvyan, 1928 ; Knight and Hoblyn, 1934) though widely different on different soils (Rogers and Vyvyan, 1934). The constancy arises from the growth increments to stem and root being in a constant ratio ; even after heavy stem pruning these increments are still in the same ratio (Knight, 1934). Thus the stem and roots are growing, season by season, at the same percentage rate, otherwise the ratio would change. This implies some mutual mechanism regulating their respective rates of growth.

It was suggested (Vyvyan, 1934) that this mechanism might be a factor in the reciprocal effect of scion and rootstock, for, when two varieties with different growth rates are combined as stem and root in one tree, they must henceforth have the same growth rate ; thus, the growth rate of one or both must change. The growth rate of the composite tree may possibly bear no fixed relation to that of either the scion or of the rootstock variety when these are grown as independent trees, or, on the other hand, the resultant rate may be determined by the respective growth rates of the stock and scion when independent. If the latter, the growth rate of the composite tree could be predicted if the growth rates of the components were known. The obvious method of finding which of these possibilities was true was to combine two varieties with different growth rates, say A and B in all four possible ways—A/A, A/B, B/A, and B/B—and to compare the mean of the combinations where scion and rootstock in each tree were of the same variety (' like ' unions) with those where they were of different varieties (' unlike ' unions), viz. A/A and B/B compared with A/B and B/A.

The experiment was started in 1936 using as A and B the dwarfing and vigorous rootstocks M.IX and M.XII ; a third rootstock, M.IV, was included because it had been shown to behave in an interesting, aberrant manner (Hatton, 1923). If this variety is called C, there were nine kinds of trees—A/A, A/B, A/C, B/A, B/B, B/C, C/A, C/B, and C/C. The experiment was finished in 1939, further work being deferred owing to the war. When the results came to be examined it was found that the mean value for trees of unlike combinations—A/B, A/C, B/A, B/C, C/A, and C/B—was approximately the same as that for trees of like combinations—A/A, B/B, and C/C—though slightly lower ; and further that a variety had far more effect on growth when used as a stock than when used as a scion.

Further questions then arose. Is the difference in growth of two varieties, when used as scions, the same, irrespective of the rootstock on which they are both worked ? And, conversely, is the difference the same when they are used as stocks, irrespective of the variety used as the scion ? The 1936 experiment was ambiguous on this point, for, of the three pairs of values showing the relative effect of A and B as scions, viz. A/A–B/A, A/B–B/B, and A/C–B/C, two include ' like ' combinations. For valid comparisons it is necessary to have at least four varieties to permit the comparison of two of the varieties against the different background of the other two ; there must be only ' unlike ' combinations involved in the comparison—A/C–B/C and A/D–B/D, or C/A–C/B and D/A–D/B, etc., thus avoiding any ' like ' combinations. Various other points required examination, e.g. the effect of the union itself, as when trees in which both stock and scion are of the same clone are compared with the unworked clone ; the relative growth rate and nett assimilation rate of composite trees as compared with those of the components ; stock and scion influence on the seasonal aspects of growth. To settle these points a new experiment was planted in the spring of 1950.

1950 experiment.

The treatments chosen were a symmetrical combination of four varieties in pairs, together with the unworked stocks (Table I).

TABLE I.

EXPERIMENTAL COMBINATIONS OF THE FOUR CLONES M.II, M.IV, M.IX, AND M.XVI.

Stocks.	Unworked stocks.	Scions.			
		M.II.	M.IV.	M.IX.	M.XVI.
M.II	II	II/II	IV/II	IX/II	XVI/II
M.IV	IV	II/IV	IV/IV	IX/IV	XVI/IV
M.IX	IX	II/IX	IV/IX	IX/IX	XVI/IX
M.XVI	XVI	II/XVI	IV/XVI	IX/XVI	XVI/XVI

Rootstock varieties rather than customary scion varieties were used as they were the only ones available in sufficient quantity, and because of their known gradation in vigour. Six replicates of the set of 20 treatments were considered the most that could be dealt with at each sampling. The land available was therefore laid out in six blocks of 20 randomized plots. To give adequate choice of material for several years each plot contained 26 plants of the appropriate rootstock at 1 yard square.

They were planted in March, 1950, and budded in June, two buds being inserted as a precaution. The rootstock was cut back the following March to a 4-inch snag to which the young scion growth was tied in. The unbudded treatments were similarly snagged back and a bud in the corresponding place allowed to grow out. Snags were removed the next winter. All parts removed were weighed individually. Where both buds had taken, the upper one was picked off when about 2 inches long, except where it was much stronger than the lower. The plants remaining after two years' sampling were further thinned to leave a spaced stand of 9 trees per plot. Cultural treatments were normal.

Sampling and records.

One tree from each plot was sampled at what were considered to be key points in the season's growth, i.e. at bud break of M.II and M.IX scions, in June (most rapid extension growth), in August (extension growth ceasing), in September-October (final leaf area), and in mid-winter (dormant period). Except in the earlier harvests the leaves were removed in the field in as few days as possible ; at the same time the leafless scion stems were cut off, and, after these had been analysed, the rootstocks were dug up. Much of the fine root was lost, but as this is a small fraction of the weight of the root, the error so introduced was small (Rogers and Vyvyan, 1928). All but the thicker woody fractions were stored in closed tins ; fresh weights were taken within three hours, and dry weights after drying at 90–95° C.

At each harvest records have been taken on a number of features of tree growth. It is hoped to define form in trees and to analyse the spatial distribution of the branches ; to do this position, length, diameter, and, where possible, weight of each branch have been recorded. Additional records were also taken to enable estimates to be made of the area of the cambium in roots and shoots. Throughout the experiment records have been taken of the progress of bud-break, extension growth, leaf-fall, flowering, etc. Where the uniformity of behaviour made it unnecessary to record each tree separately, all observations have been made on two typical trees in each plot. These trees will be the last to be sampled in the experiment. Diameters of stock and of main scion stem have been measured each winter. In 1953 the onset of flowering introduced a disturbing factor. All the trees were deblossomed except for three on each plot reserved for a subsequent experiment on the combined effect of flowering and fruiting on the growth of the tree.

Summary.

An account is given of past experiments and of a new experiment for the further study of the mechanism of the reciprocal effect of scion and stock on growth and form in young apple trees.

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EXPERIMENTS WITH APPLE LEAF-BUD CUTTINGS

By R. J. GARNER, E. S. J. HATCHER* and CATHERINE P. NICOLL

Leaves have often been detached and cultured for physiological and pathological studies (Yarwood, 1946). Normally such leaves have been used immediately, but recently the advantage of first rooting them has been stressed (Gregory and Samantarai, 1950). In horticulture the leaf cutting method of propagating plants has long been in use (Marston, 1953) and a great variety of plants has been examined in this respect (Hagemann, 1932).

In their studies of the factors controlling the rooting of isolated leaves Gregory and Samantarai worked with dwarf bean and ivy, having first determined that both species could be induced to root from the leaf petiole by appropriate growth substance stimulation. The suggestion that attempts should be made to obtain apple leaves on their own roots for use in physiological studies at once directed attention to the propagating problem involved. The intention was to produce a finite organism incapable of utilizing assimilates or nutrients for shoot extension.

The difficulty of rooting apple leaves was referred to by Priestley and Swingle (1929) and, similarly, Stoutemyer (1937) found that, with the exception of leaves from juvenile shoots, they rarely rooted. Furthermore, when roots formed no adventitious bud appeared, a complication he overcame by taking the leaf with its axillary bud. Leaf-bud cuttings were, however, almost as shy to root as the leaf cuttings themselves. Stoutemyer had then not used growth substances and thus the preliminary step was to examine the effects of such treatment.

Exploratory experiments were made in 1951 with a range of apple rootstock varieties from which valuable guidance was obtained for subsequent procedure. The following were the main indications :

(i) most of the rootstock varieties were shy to root, those showing most promise being M.V and M.VIII ;
(ii) the leaf-bud cutting rooted more readily than the leaf cutting ;
(iii) rooting occurred, for the most part, only after a growth substance treatment had been given ;
(iv) application of the growth substance as an instantaneous alcoholic dip (Hatcher and Garner, 1951) was effective, indole-3-butyric acid (IBA), α-naphthaleneacetic acid (NAA), and 2,4,5-trichlorophenoxyacetic acid all producing response.

Accordingly the two rootstocks M.V and M.VIII were chosen for the physiological and nutritional studies, and a more detailed investigation was made of the rooting behaviour of M.V, the results of which are now described.

Experimental procedure.

In all the experiments the cuttings were planted in a medium composed of equal parts of peat and coarse sand in seed boxes, four rows of ten cuttings to a box. The boxes were placed in a propagating case with bottom heat, supplied electrically, at an average temperature of 65° F. The unit was a single row of cuttings, treatments being fully randomized in blocks. Growth substance treatment, where given, was an alcoholic dip of IBA, unless otherwise stated at a concentration of $\frac{1}{2}$ mg. per ml. The duration of each experiment was normally one month, after which the cuttings were graded, and root counts and other observations made. There were two groups of experiments, one concerned with the behaviour of the leaf-bud cutting relative to its original position on the shoot (source experiments), the other with its behaviour in terms of the various parts composing it (technique experiments).

Source experiments.

Leaf-bud cuttings were taken from a range of positions on the shoot at three times during each of the summers of 1952 and 1953, growth substance treatment being applied in all cases.

1952 experiments.

The first experiment in 1952 began on 10th June when the stoolbed shoots had grown about 25 cm. with 13 or 14 opened leaves ; every third leaf down the shoot was used. Subsequent rooting of the leaves (Table I) ranged from a minimum of 1·2 per cent at the apex, to a maximum of 90 per cent at the tenth leaf, falling to 67·5 per cent at the base. Each positional level differed significantly from its neighbour.

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TABLE I.

SOURCE EXPERIMENTS, 1952—PERCENTAGES OF LEAF-BUD CUTTINGS ROOTED.

Date.	Shoots used.		Position of leaf from apex and percentage rooting.									'F'.
	Length.	No. of leaves.	1	3	4	5	7	9	10	11	13	
	cm.											
10th June ..	25	13-14	1·2	—	47·5	—	78·7	—	90·0	—	67·5	63·89 xxx
16th July	50	20-24	0·0	15·0	—	17·5	35·0	60·0	—	62·5	52·5	14·62 xxx
9th September ..	75	30-32	10·0	20·0	—	35·0	32·5	35·0	—	37·5	35·0	2·01 n.s.

xxx ≡ P < 0·001. n.s. ≡ not significant at P = 0·05.

In the experiments of 16th July and 9th September alternate leaves from the tip down to the thirteenth were used. There was a progressive decline as the season advanced in the amount of rooting and a corresponding diminution in the effect of position, which by 9th September was no longer significant (Table I). The data support the thesis that a fully developed, but not senescent, leaf is essential for high rooting.

1953 experiments.

The 1953 series of experiments was somewhat modified in an attempt to observe rooting relative both to the maturation and the ageing of the leaf. Five alternate leaves working downwards from the apex, and three alternate leaves working upwards from the base were used ; the residual leaves in between increased in number with the growth of the shoot from nil on 17th June to eighteen on 20th August. To reduce the risk of damage to the basal leaves, common on mounded stools, two-year-bedded nursery plants had been cut back to 30 cm. the previous winter so as to give shoots arising above ground level. The percentage rooting values are given in Table II.

TABLE II.

SOURCE EXPERIMENTS, 1953—PERCENTAGES OF LEAF-BUD CUTTINGS ROOTED.

Date.	Shoots used.		Position of leaf from apex and percentage rooting.					No. of leaves in between.	Position of leaf from base and percentage rooting.			'F'.
	Length.	No. of leaves.	1	3	5	7	9		5	3	1	
	cm.											
17th June ..	32	14	0·0	20·0	20·0	12·5	25·0	0	22·5	37·5	40·0	4·21 xx
17th July ..	57	26	0·0	10·0	12·5	15·0	15·0	12	22·5	20·0	30·0	1·53 n.s.
20th August	66	32	5·0	12·5	10·0	15·0	22·5	18	10·0	7·5	10·0	1·30 n.s.

xx ≡ P < 0·01. n.s. ≡ not significant at P = 0·05.

Far fewer cuttings rooted than in 1952, but again there was a progressive decline as the summer advanced, the maximum percentages for rooting in the different experiments being 40, 30, and 22·5 respectively compared with 90, 62·5, and 37·5 in 1952. Both in June and July the maximum rooting was located at the base of the shoot, but in August the percentage of lower cuttings that had rooted had fallen off.

The number of roots produced by a cutting was not influenced by either its position on the shoot, or the time of separation. The contrast was again between the two years, 3·3 roots per cutting in 1952 and only 1·6 roots in 1953.

The limited rooting of the top cutting was associated with low survival, though in 1952 many non-rooted cuttings had callused and were healthy at the end of the earlier experiments; in 1953, however, even in the June experiment many of the upper cuttings had died.

TABLE III.

TECHNIQUE EXPERIMENTS—BEHAVIOUR OF CUTTINGS.

Date.		Leaf-bud cutting.						Leaf cutting.						'F'.
	Growth substance concentration	0		½		1		0		½		1		
	Presence or absence of bud or petiolar base	Bud.						Petiolar base.						
		+	−	+	−	+	−	+	−	+	−	+	−	
16th July, 1952	Per cent rooted	15·0	5·0	55·0	77·5	—	—	—	—	—	7·5	—	—	13·58 xxx
	Per cent dead	5·5	0·0	0·0	10·0	—	—	—	—	—	7·5	—	—	—
	Number of roots per cutting	1·3	2·0	3·2	4·5	—	—	—	—	—	1·0	—	—	8·87 x
9th September, 1952	Per cent rooted	15·0	22·5	32·5	35·0	—	—	—	—	—	0·0	—	—	2·36 n.s.
	Per cent dead	27·5	22·5	42·5	52·5	—	—	—	—	—	22·5	—	—	—
	Number of roots per cutting	1·6	1·2	2·5	3·3	—	—	—	—	—	—	—	—	—
17th June, 1953	Per cent rooted	—	—	25·0	27·5	32·5	35·0	—	—	5·0	2·5	0·0	0·0	31·17 xxx
	Per cent dead	—	—	42·5	45·0	47·5	57·5	—	—	52·5	22·5	55·0	35·0	—
	Number of roots per cutting	—	—	2·3	2·0	2·6	3·0	—	—	1·7	2·0	—	—	1·01 n.s.

xxx ≡ $P < 0·001$. x ≡ $P < 0·05$. n.s. ≡ not significant at $P = 0·05$.

Technique experiments.

The leaf-bud cutting may be regarded as an entity composed of lamina, petiole, petiole base, stem heel, and axillary bud. The technique experiments were designed to evaluate the relative importance of these components, two in 1952 being concerned mainly with the axillary bud, and one in 1953 with petiole base and stem heel as well.

The experiments were in parallel with the source experiments already described, using intermediate leaves from the same shoots. The results of all three experiments are summarized in Table III.

The two experiments in 1952, while manifesting different general levels of rooting associated with occasion, agree as to the effects of excising the axillary bud. The differences were statistically insignificant, whether on percentage rooted, or the number of roots produced. The main effect was the reaction of the leaf-bud cutting to growth substance treatment, the mean rooting percentage increasing from 14 to 50, and the root number from 1·5 to 3·4. The weakest rooting occurred on the leaf cutting proper which after growth substance treatment averaged only 3·7 per cent rooted and 1·0 roots per cutting.

The 1953 experiment, planted on 17th June, made further comparisons, with the following four types of cutting :

1. normal leaf-bud cutting ;
2. ditto with bud excised ;
3. leaf cutting, pulled away to include base of petiole ;
4. normal leaf cutting, with petiole cut above base.

Two concentrations of growth substance ($\frac{1}{2}$ and 1 mg./ml.) were applied to each type of cutting in order to discern any trace of differential penetration due to bud excision.

The results showed unequivocally that the essential component for rooting of the cutting is the presence of the heel of stem tissue, with no differences between the presence or absence of the axillary bud on the one hand, and the presence or absence of the petiolar base on the other.

There was no significant differential influence of growth substance concentration, either in relation to percentage rooted or root number per cutting. The normal leaf cutting, without petiolar base, while rooting negligibly callused well and survived best.

Discussion.

These experiments have shown that the apple rootstock variety M.V may be propagated from leaf-bud cuttings provided that growth substance stimulation is given, the reacting tissue being the small piece of stem included in preparing the cutting. Excising the axillary bud does not interfere with subsequent rooting, rather the reverse, showing that any influence of the bud has already been exerted. In the absence of the stem tissue, the leaf cutting, however carefully made to include the extreme base of the petiole, rarely roots.

The degree of rooting is influenced both by the time of detaching the cuttings and their position on the shoot. Best results are obtained in early summer when the shoot is growing actively, the optimal position being towards the base. As the general level of rooting falls the influence of position lessens. In terms of the individual leaf the propagative period extends over most of its life.

The challenging feature of these results is the marked diminution in rooting both in frequency and degree from 1952 to 1953. That it is consistent throughout the experiments, irrespective of occasion, indicates the operation of a source factor, especially as a good measure of control was exerted both in the composition and temperature of the rooting medium. The seasonal growth environments of the source shoots themselves could have been responsible, but another possibility must not be overlooked, the differing cultural environments of the parent plants in the two years.

This last possibility suggests that the leaf-bud cutting might be used to obtain an index or characteristic of propagative quality within a clone. Stoutemyer (1937), whose work has already been mentioned, records that leaf-cuttings from shoots in the juvenile stage root well (even without growth substance stimulation) and therefore this might prove a useful test for this condition, particularly valuable as the shoot can be ' sampled ' without itself being removed.

Finally, the original purpose of these experiments, to produce a finite leaf-root system for physiological studies (Ruck and Bolas, in the press), was achieved with M.V, which though rarely rooting on its own petiole when taken as a leaf cutting, is readily rooted as a leaf-bud cutting, the unwanted bud being excised before or after establishment. The bud is in fact not directly involved, though the presence of the stem heel is practically essential, a point which arouses curiosity about the latter's regenerative behaviour, which may be independent of the type of leaf. The behaviour of the stem heel beneath various laminae might well be investigated by grafting.

Acknowledgements.

The authors' thanks are due to various workers who have assisted with these experiments, including Mr. E. G. Coker, who carried out the 1951 exploratory experiments ; Mr. R. G. White, a short-term voluntary worker, who was responsible for three of the 1952 experiments ; and Mr. D. W. Way, who helped in the 1953 experiments.

Summary.

By growth substance stimulation leaf-bud cuttings of the apple rootstock variety M.V have been induced to root, but the ordinary leaf cutting failed to do so. It was found that the reacting tissue was the small piece of attached stem, and not the axillary bud nor the petiolar base.

Rooting behaviour of the leaf-bud cutting is influenced by position on the shoot, and the time of separation from that shoot. Its possible use as an indicator of propagative capacity is discussed.

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PLANT PATHOLOGY

DISTRIBUTION OF RUBBERY WOOD VIRUS IN APPLE VARIETIES AND ROOTSTOCKS

By A. F. POSNETTE and R. CROPLEY

The occurrence of the rubbery wood virus in the apple rootstocks M.I and M.IX at East Malling Research Station was reported in an earlier paper (Posnette and Cropley, 1952). Subsequent trials, which have demonstrated the presence of the virus in other rootstocks and also in many scion varieties, are described in this progress report.

Method.

The sensitive variety Lord Lambourne was used as the indicator. Rootstock stools were tested by budding or grafting two stocks per stool (or three of certain clones) with healthy Lord Lambourne scions of a previously tested clone. The scion was tested by the hand-bending method (Prentice, 1950) at the end of the first season's growth and again, in a proportion of the tests, at the end of the second season.

Scion varieties were tested by double-grafting or double-budding, using M.II rootstocks from stoolbeds known to be free from the rubbery wood virus, and healthy Lord Lambourne scions. In the double-grafting method, scion wood from the trees under test was bench-grafted to the Lord Lambourne scions in the winter ; the double-grafts were stored in boxes of peat until March, when they were grafted to the rootstocks so that the scion under test formed the intermediate and the Lord Lambourne the top scion.

In the double-budding method, two shield buds were inserted one above the other, about 2 inches apart on each stock, the higher (' indicator ') bud being the Lord Lambourne indicator, and the lower (' index ') bud, taken from the tree under test. Only the indicator bud was allowed to grow, the bud on the other shield being rubbed off. The maiden trees were examined for symptoms in the following autumn. Two indicator plants were used for each tree tested.

The controls were of two types : (*a*) ' negative ' controls in which healthy indicator scions were grown on 10 per cent of the rootstocks as a check on the health of both scions and rootstocks, and (*b*) ' positive ' controls in which infected Lord Lambourne scions were used in the position of the index bud in the double-budding method.

Results.

The reliability of the method.

The efficiency of the test depends on the health of the rootstocks and the Lord Lambourne clone used, and on the regularity with which symptoms develop on the indicator. In these tests, the health of the M.II rootstocks and of the Lord Lambourne scions is placed beyond doubt by the complete absence of rubbery wood from the 600 negative controls. This conclusion is supported by the previous experiment on the M.II rootstocks (Posnette and Cropley, 1952), where the trees have now been under observation for three seasons ; and also by further tests on the M.II stoolbeds as described later in this paper.

The transmissibility of the disease, already reported by Prentice (1950), was amply confirmed by the positive controls, in which a shield bud from a rubbery Lord Lambourne tree was placed on the M.II stock below the healthy indicator bud. Out of 100, 96 indicators were rubbery at the end of the first season's growth.

The efficiency of the double-budding method of indexing, with observations on the first year's growth, can also be estimated from the results of testing 110 trees in one orchard (Plot C.12). Each tree was indexed on two Lord Lambourne indicators which, if the method could be relied upon invariably to give results in one year, should have been either both rubbery or both normal at the end of the first season's growth, according to the health of the particular tree being indexed. Of the 110 pairs of indicators, both plants were normal in 46 and both rubbery in 41 ; but 23 pairs consisted of one rubbery and one normal plant. These 23 normal plants are almost certainly infected, since their partners, inoculated from the same tree, showed symptoms. The chances of two such latent infections occurring together is $(\frac{23}{128})^2$, or 3 per cent. Hence it can be expected that only one or two of the 46 trees, whose indicators were both healthy, will prove to be infected when second-year growth is examined.

Two factors have been found to influence both the proportion of indicators which develop symptoms in the first year's growth and the degree of rubberiness ; viz. the relative position of the indicator and index buds, and virus strain variation.

Relative position of buds.

During symptom recording in the autumn, it was noticed that the index buds had not always been placed vertically below the indicator buds. A check on the position of the buds in relation to the degree of rubberiness developed on the indicator showed that slight lateral displacement did not affect symptoms. In a sample of 252 plants examined, the buds were vertically aligned on 133, of which 11·3 per cent were normal or only slightly rubbery. The buds were laterally displaced between 10° and 45° on 111 plants, of which 18·0 per cent were not rubbery. Of 8 infected plants on which the index bud was on the side of the stock opposite the indicator bud, only 3 were definitely rubbery. To ensure the rapid transmission necessary for the development of symptoms in the first season's growth, the index and the indicator buds should be placed on the same side of the stock, but they need not be exactly aligned.

Strain variation.

The virus used for the positive controls originated from the rootstock M.IX and was selected as intermediate in severity. Lord Lambourne scions infected with this strain feel distinctly rubbery, but are sufficiently stiff to remain erect. More severe strains induce ' weeping ' growth (Posnette and Cropley, 1952, Fig. 1), while milder strains cause no or only slight rubberiness in the first year, and can be diagnosed with certainty only on two-year-old wood.

The tests on M.I rootstocks illustrate the behaviour to be expected with mild strains of the rubbery wood virus. Twelve stools of M.I were tested in 1950 by budding five rootstocks from each with healthy Lord Lambourne. In the autumn of 1951, 15 of the 53 surviving maiden trees, representing 6 stools, were diagnosed as slightly rubbery. By the autumn of 1952, 38 trees were rubbery, and 45 in 1953, no stools being virus-free. Six of these stools were retested by grafting in 1952 ; 15 out of 28 indicators were rubbery after one season's growth, and 27 after two. The virus strain in M.I usually requires two years for the development of definite symptoms, and, even then, they are not very pronounced. It might be argued from this that the rootstock influences symptom expression rather than that differences in virus strains occur ; but the evidence from extensive tests using one rootstock throughout confirms that extreme differences in rubberiness are caused by virus variation.

Tests on rootstock clones.

The Research Station stoolbeds of the rootstocks M.I, M.II, M.IV, M.VII, and M.XVI were examined by testing two stocks from each of 100 stools chosen at random. In M.IX, M.XII, and Crab C, fewer stools were selected and three stocks from each were tested. The results at the end of the first year's scion growth (Table I) confirm the previous finding of a high rate of infection in M.I and M.IX ; they also show a low proportion of infected stools in M.IV and Crab C.

TABLE I.

DISTRIBUTION OF RUBBERY WOOD VIRUS IN THE EAST MALLING STOOLBEDS OF THE MALLING SERIES OF ROOTSTOCKS.

Rootstock.	No. of stools tested.	No. of stocks budded from each stool.	No. of stools infected.*	Percentage of stools infected.*
M.I	100	2	83	83
M.II	100	2	0	0
M.IV	100	2	1	1
M.VII	100	2	0	0
M.IX	25	3	20	80
M.XII	17	3	0	0
M.XVI	100	2	0	0
Crab C	25	3	2	8

* More plants may show symptoms after two years.

Ten stools of each of the Malling-Merton rootstocks MM.101 to MM.114 were tested and were, on the basis of one year's observations, found to be free from rubbery wood virus. Also tested and found free after one year's observation were M.XXV, 90, 96, and 411.

All available stools of the following rootstocks in the M.IX Crosses series were tested and no rubbery wood symptoms found after the first year's growth :

341, 3413, 3414, 3426, 3428, 3430, 3431, 3432, 3436 and 3438.

Tests on orchard trees.

In the spring of 1952, an extensive programme was commenced with the dual purpose of finding virus-free trees for the propagation of the more important apple varieties, and of investigating the distribution of rubbery wood virus in the field experiments on the Research Station. 2,270 trees were tested by double-grafting or budding in 1952, and the results of the first year's observations on the indicator plants are summarized in Table II. The results of the 1953 tests on more than 2,500 trees are not yet available.

Probably the trees in some orchards are infected because they were raised on previously infected rootstocks, M.I and M.IX being particularly suspect. In other orchards, the distribution of infection

TABLE II.

DISTRIBUTION OF RUBBERY WOOD VIRUS IN APPLE VARIETIES.

Variety.	No. of trees tested.	Number infected.
Allington Pippin	1	0
Arthur Turner	1	0
Beauty of Bath	1	0
Belle de Boskoop	1	0
Blenheim Orange	2	0
Bramley's Seedling	64	14
Charles Ross	2	0
Cox's Orange Pippin	624	52
Crawley Beauty	1	0
Early Victoria	1	0
Edward VII	1	0
Egremont Russet	6	1
Ellison's Orange	265	17
Golden Delicious	1	1
Grenadier	57	5
Howgate Wonder	5	0
James Grieve	25	5
Jonathan	283	13
King's Acre Pippin	4	0
Lane's Prince Albert	200	8
Laxton's Advance	3	0
Laxton's Epicure	5	0
Laxton's Fortune	2	1
Laxton's Superb	244	192
Lord Derby	2	0
Martinmas	5	0
Michaelmas Red	6	4
Miller's Seedling	4	3
Newton Wonder	1	0
October Pippin	2	0
Orleans Reinette	6	2
Owen Thomas	1	0
Ribston Pippin	6	4
Royal Jubilee	1	0
St. Edmund's Russet	4	2
Stirling Castle	1	0
Sunset	2	2
Tydeman's Early Worcester	3	0
Tydeman's Harvest	4	0
Tydeman's Late Orange	3	0
Wagener	1	0
Winston	2	0
Worcester Pearmain	417	42
Total	2,270	368

shows that infected scion-wood was used. On Plot L.6, for example, where rows of Cox's Orange Pippin alternate with rows of Laxton's Superb, both on M.II, all the Cox trees were found to be healthy, but over half of the Superbs were infected. On Plot L.5, 41 of the 54 Laxton's Superb trees were infected and only 2 of the 54 Worcester Pearmain.

Since both Cox's Orange Pippin and Worcester Pearmain were susceptible varieties on other plots, the distribution of infection on L.5 and L.6 would seem to indicate that the virus rarely, if ever, spreads in young orchards ; in old orchards, where root-grafting is more likely to occur, tree-to-tree spread may be more frequent.

The presence of the rubbery wood virus in one of the oldest trials of the Malling clonal rootstocks, planted in 1920, is evidence that latent infection has occurred for many years. The virus was almost certainly widely dispersed before the variety Lord Lambourne was distributed, and the suggestion (Darlington and Mather, 1949) that the virus originated from plasmagenes during the propagation of that variety seems most improbable.

Acknowledgements.

This investigation has been greatly assisted by members of the research staff who collected scion wood from experimental trees under their control. We wish particularly to thank Mr. T. V. Dixon, who supervised the extensive nursery work with so much care.

Summary.

A method of indexing apple trees for rubbery wood virus is described. Over 90 per cent of the Lord Lambourne indicators, when grafted with infected material, developed symptoms in the year of inoculation, or in the year following when budded. Two years may be required, however, for the diagnosis of mild strains of the virus. Different degrees of rubberiness can be caused by virus variation.

The relative positions of the index and indicator buds on the rootstock were found to be important. They should be placed on the same side of the stock, though they need not be exactly aligned.

A test of M.I and M.IX stoolbeds on the Research Station showed 80 per cent to be infected. Some infected stools of M.IV and Crab C were also found. No virus was detected in the new Malling-Merton series or in nine rootstocks of the M.IX crosses tested. Virus-tested sub-clones of the Malling series are now being multiplied rapidly for general use.

A test of a large number of apple varieties growing on the Station showed many to be infected with rubbery wood virus ; there is evidence that it had been distributed by propagation rather than by spread from tree to tree in the orchards.

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FIELD STUDIES ON VIRUS DISEASES OF STRAWBERRIES

II. SEASONAL PERIODS OF VIRUS SPREAD

By A. F. POSNETTE and R. CROPLEY

For the control of virus diseases of strawberries, the first requirement is that there should be minimal sources of infection *within* newly planted fields ; this is being achieved through the production of virus-free planting stock under the Special Stock Certificate Scheme of the Ministry of Agriculture. The second step is the control of the aphid vectors which introduce viruses from other strawberry fields, and then spread them so rapidly that every plant may become infected within four years of planting (Posnette and Bovey, 1952). For the prevention of virus spread by controlling the vectors, not only should their migration habits and seasonal fluctuations in population be known, but also the seasonal periodicity in virus spread. Dicker (1952) has studied the biology of the most important vector of strawberry viruses, the aphid *Pentatrichopus fragaefolii* (Cock.). The results of three years' investigation (1951-53) of the seasonal spread of the viruses causing Yellow-edge and Crinkle are summarized below.

Method.

Virus-free plants of the Malling clone of *Fragaria vesca* were exposed to infection in the field for periods of two weeks as follows, and then kept in an insect-proof glasshouse for symptoms to develop. Fifty potted plants were plunged between fruiting plants in a variety collection containing one-, two- and three-year-old plants of 33 varieties, in which the incidence of crinkle and yellow-edge viruses was known to be high. No sprays were used on the plot during this investigation. At the end of the two weeks exposure period, the plants were replaced by another batch of 50 and examined for aphids before being dipped in nicotine solution.

This procedure was modified on three occasions when there were insufficient plants. The first and the last batches in 1951 (May and December) and the first in 1952 (March) were exposed for four weeks instead of two. The number of plants infected during these periods has been halved in the results shown in Fig. 1.

During the summer months when virus symptoms develop rapidly, the *Fragaria vesca* plants were examined periodically for about 12 weeks before being discarded, but in the winter months they were kept for as long as 20 weeks in the heated glasshouse.

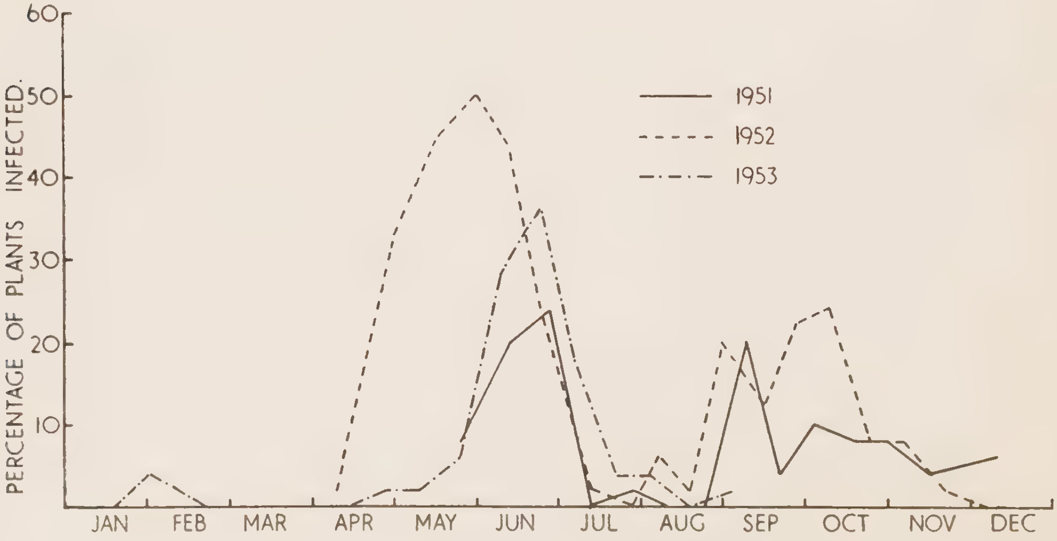

FIG. 1.

Seasonal spread of virus to exposed plants, 1951-1953.

The viruses infecting these plants were identified according to their symptoms, which have been described by Prentice and Harris (1946) and by Prentice (1948, 1949, 1952); uncertain diagnoses were checked by aphid transmission with serial transfers to determine virus persistence in the vector.

Symptoms of virus 3 in *F. vesca* are masked by those of virus 1, so that infected plants could be placed in one of the following groups, with viruses 1 and 2 predominating:

Virus 1 group.	Mottle and mild crinkle viruses which do not persist in the Strawberry Aphid for more than three hours.
Virus 2 group.	Mild yellow-edge viruses which persist for several days in the vector, and often have a latent period of 24 hours.
Viruses 1+2.	Multiple infections.
Virus 3 group.	Crinkle viruses which persist in the vector for many days. These viruses have a latent period in the vector of up to 23 days from the commencement of the infection feed.
Unidentified viruses.	Viruses, such as virus 4, which cannot be diagnosed with certainty on *F. vesca.*

Results.

Virus spread.

The percentage of plants that became infected during each two-week period in 1951, 1952 and 1953 is shown in Fig. 1, in which the different viruses are considered together. Although the proportion of plants infected varied from year to year, probably reflecting differences in the aphid population, the general trend was the same each year. The peak period of spread occurred in May or June, followed by a period of little or no spread in July or August. There was a long period in the autumn when spread occurred continuously, but at a lower rate than in the spring.

When the virus groups 1 and 2 were considered independently, it was found that their pattern of spread differed from year to year and particularly between spring and autumn. In 1952 the proportion of plants infected with virus 2 was higher than in 1951 and 1953. In the spring periods, there was considerable spread of both virus groups, but autumn infection was almost entirely of virus 2; the spread in 1952 is shown in Fig. 2.

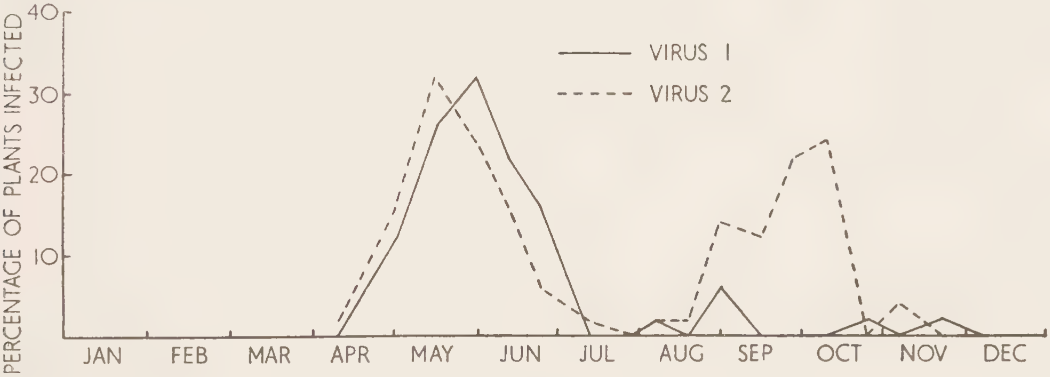

FIG. 2.
Seasonal spread of virus 1 and virus 2, 1952.

Aphid numbers.

The amount of virus spread, measured by the number of plants becoming infected, depends more on the mobility than on the number of vectors. A few active insects would be expected to infect more plants than would many static insects. The number of exposed plants on which aphids were found at the end of each period should therefore be a measure of the population of mobile and therefore *effective* vectors. In Fig. 3 the percentage of aphid-infested and of virus-infected plants are shown to be related.

The total number of aphids on the permanent plants on the plot was estimated by sample counts in 1952, and the results are shown in Fig. 3. Peak populations occurred in spring and autumn and the appearance of winged aphids coincided with these peaks. Consequently, it is not possible to decide whether the movement of aphids to the plunged plants was due primarily to flying aphids, or to

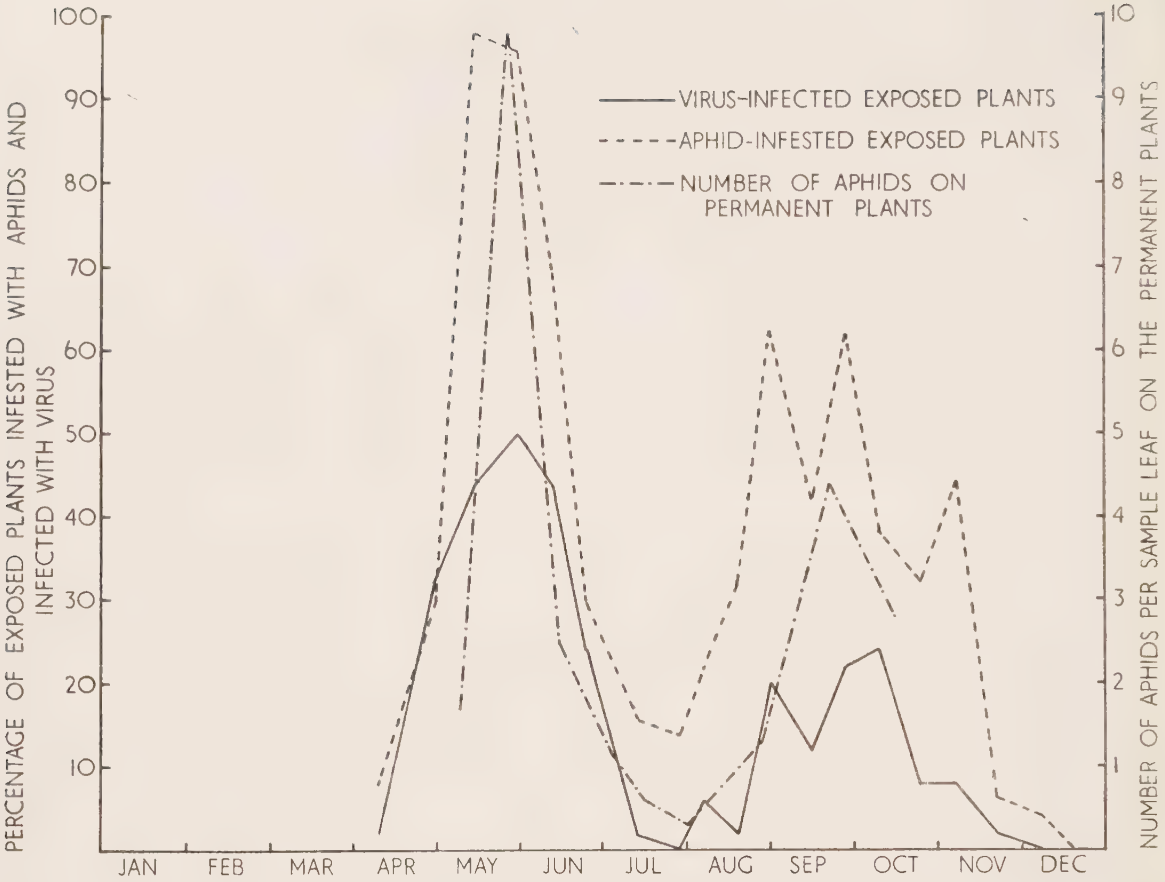

Fig. 3.
Aphid populations and virus spread, 1952.

crawling aphids being more active in dense populations. The virus spread shown in Fig. 1 could have been caused by winged or by crawling aphids; it seems probable that both forms were responsible.

Grease-banding experiment.

During 1953, an attempt was made to distinguish between virus spread by winged and by wingless aphids. In addition to the 50 unguarded plants, another 50 plants were exposed during each period and these were guarded against crawling but not against flying insects. The guards consisted of two collars, an inner one of xylonite, 6 inches high and 9 inches in diameter, and an outer one of roofing felt 8 inches high and 12 inches in diameter. They were pushed about 1 inch into the soil around the pots, and the outer surface of the xylonite and the inner surface of the felt were coated with a proprietary grease-banding compound. The sticky sides facing each other were protected by their position from rain and from much of the wind-borne dust; the grease was disturbed every second week to prevent a dust film forming, fresh grease being added when necessary.

Aphids were first recorded on the unguarded plants on 4th May, and between then and 21st December, 128 out of 850 plants became infested. In the same period, aphids were found on only 26 of the 850 guarded plants, 14 of which became infested in one period between 16th and 29th June. Only one guarded plant has so far developed virus symptoms, compared with 50 unguarded plants.

Discussion.

The low infestation of the guarded plants suggests that the guards, which covered the lower half of the foliage of the potted plants, afforded some protection against flying aphids. The rapidity with which strawberry plants are usually colonized by aphids in the fields (Greenslade, 1941 ; Dicker, 1952) shows that aphid flight is more frequent than the results of this experiment would indicate. It is obvious that only winged insects can spread viruses into strawberry fields, but further experiments are needed to assess the relative importance of winged and of wingless aphids in virus spread *within* the field.

This investigation has clearly shown that virus spread occurs mainly at two periods of the year—early summer and autumn. Virus spread in early summer, when both the flight period and the peak population of aphids occur, was to be expected, and control measures have usually been timed to meet this danger. The amount of spread found to take place in the autumn was unexpected, however, and as most of the plants were then infected with virus 2, the yellow-edge virus, this is a dangerous time from the propagation standpoint. Even in a sensitive variety like Royal Sovereign, plants infected in the autumn would not develop symptoms until the following spring. Infected plants would be distributed even though careful inspection throughout the growing season had revealed no virus symptoms ; this is probably the explanation for the high incidence of Yellow-edge which occasionally appears in young plants grown from certified stock.

As this investigation was conducted on an unsprayed fruiting bed, the results do not necessarily apply to runner beds which are sprayed in summer. Unless they are isolated, however, runner beds may become infested from fruiting beds in the autumn, and the use of insecticides may then be necessary for virus control. There is little doubt that the control of aphids on fruiting beds in September would reduce the spread of the yellow-edge virus.

Acknowledgements.

The writers are indebted to Dr. G. H. L. Dicker and Mr. J. B. Briggs for help in the identification of aphid species, and for the estimate of aphid populations on the permanent plants.

Summary.

By exposing successive batches of *Fragaria vesca* plants to virus infection in an unsprayed strawberry plot, it was found that the two main periods of virus spread were during May and June, when viruses 1 and 2 (Mild Crinkle and Yellow-edge) were spread, and during the autumn, when infection was mainly of virus 2. There was close relationship between the number of aphids (*Pentatrichopus fragaefolii*) on the permanent plants in the plot, the number of *F. vesca* plants that became infested with aphids and the number of *F. vesca* plants that were infected with virus in each exposure period.

There was little virus spread to plants that were guarded from wingless aphids by sticky collars, but it is thought that these collars may have afforded some protection also from winged aphids.

The autumn period of virus spread is considered important in the propagation of strawberry plants.

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A METHOD FOR DETERMINING THE PATHOGENICITY OF STRAINS OF *VERTICILLIUM ALBO-ATRUM* ISOLATED FROM THE HOP

By P. W. TALBOYS and J. F. WILSON

Two distinct forms of Verticillium Wilt of the hop have been recognized by Keyworth (1942) ; the first, a mild disorder of widespread occurrence in hop gardens and known as fluctuating Wilt ; the second, a severe and usually lethal form of the disease, at present limited in distribution to parts of Kent, Sussex, and Surrey, and known as progressive Wilt.

It has been shown by Isaac and Keyworth (1948) that the differences between the two conditions may be attributed to the existence of at least two strains of the pathogen differing in their degree of pathogenicity to the hop.

While the diagnostic features of the two disease forms described by Keyworth (1942) and by the Ministry of Agriculture Advisory Leaflet 413 (1953) are of general application, considerable variations in symptom expression are sometimes encountered, and it may in some circumstances be difficult to decide with certainty whether a particular outbreak of Wilt in its early stages is of the fluctuating or the progressive type.

Harris (1936) related the intensity of what later proved to be fluctuating Wilt to the water content and physical condition of the soil. Isaac and Keyworth (1948) and Keyworth, Hitchcock, and Goode (1953) have noted that environmental factors may influence the severity of progressive Wilt attacks, and Keyworth and Hewitt (1948) showed that a low level of nitrogen supply to the host had a pronounced effect in reducing the severity of the disease. It is probable that the temperature, humidity, and movement of the air also influence disease expression by affecting the rate at which desiccation of the leaves takes place.

There is the further possibility that variations occur in the pathogenicity of the fungus within the two main types.

Because of such variations in disease intensity it is frequently necessary to make observations on a Wilt outbreak for at least a year before a diagnosis can be made. But the effective control of a new progressive Wilt attack depends on early and drastic action, involving the removal and destruction of infected plants and their neighbours, and isolation of the affected area. It would therefore be preferable in some cases to take eradicant action on the assumption that progressive Wilt is present, while making critical tests on the pathogen under controlled conditions elsewhere finally to determine its pathogenicity compared with isolates from known progressive and fluctuating outbreaks. So far no satisfactory laboratory method has been discovered for differentiating the two pathogenic forms in artificial culture, and any such differentiation must therefore be done on the basis of inoculation tests on the living host plant.

The method of pathogenicity testing described below has been devised to permit such an examination each year of the maximum number of isolates of *Verticillium* under comparable conditions, in the minimum space, without infecting useful land, and with little risk of cross-inoculation occurring between different isolates.

Equipment and lay-out.

The general lay-out of the experiment is shown in Fig. 1. Two rows of tanks, each divided into four units, 3 ft. × 3 ft. × 16 in. deep (internal dimensions), are constructed of 2-inch breeze-blocks on a concrete bed and covered inside and out with a $\frac{1}{2}$-inch layer of concrete. The bottom of each unit (Fig. 2) slopes to a central sump hole (A) 6 in. × 6 in. × 4 in. deep, covered with copper gauze. In an initial experimental tank the sump drained by a 1-inch pipe (B) to a second sump (C) at the side of the tank, and thus by 3-inch piping (D) to a deep soakaway. In all subsequent tanks, however, the second sump was not included, and water was piped directly to a 3-inch covered drain and so to the soakaway.

Each unit was filled to about 3 inches from the top with coarse sand.

Experimental methods.

Isolates of *Verticillium albo-atrum* from a series of typical long-standing outbreaks of progressive and fluctuating Wilt were obtained during July, August, and September, 1952. These were main-

A Method for Determining the Pathogenicity of Strains of *Verticillium albo atrum* Isolated from the Hop. By P. W. Talboys and J. F. Wilson

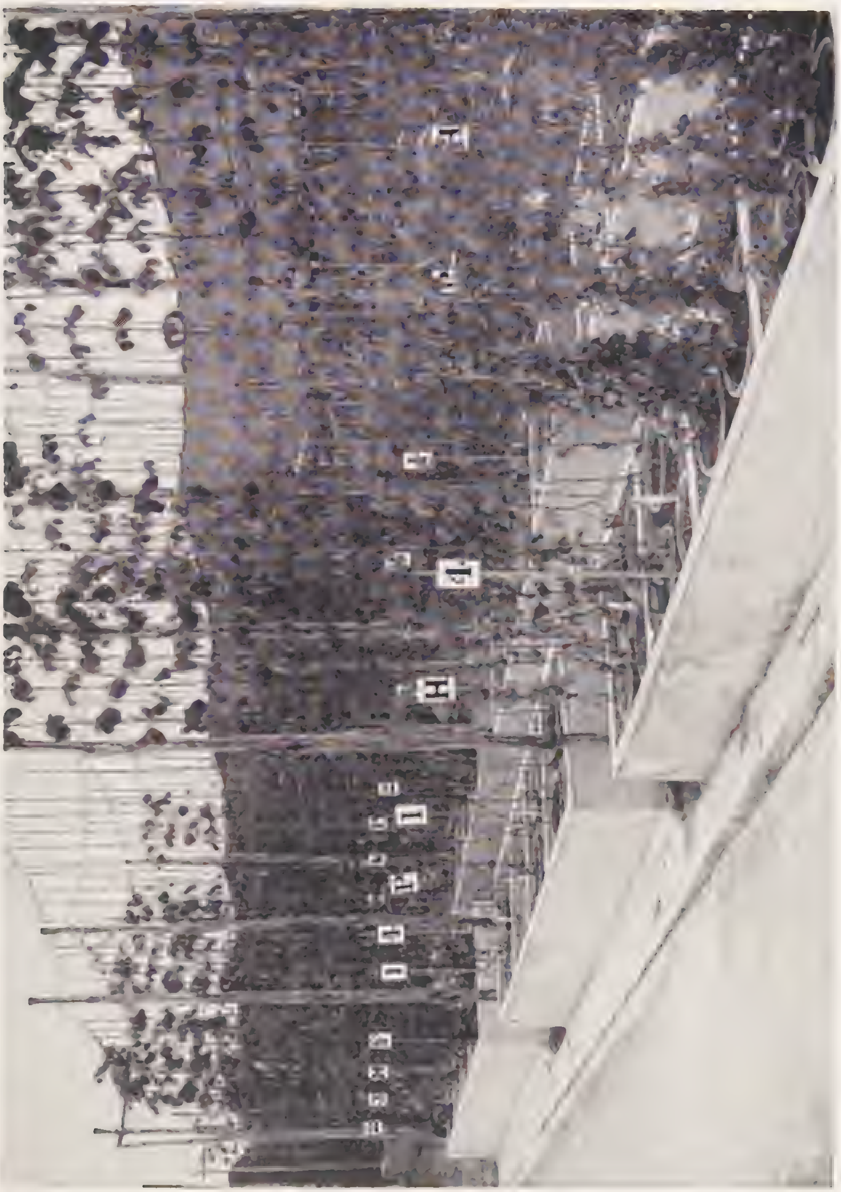

Fig. 1.

General view of the pathogenicity trial in early July.

tained on prune-lactose-yeast agar under paraffin oil until required (Buell and Weston, 1947). Inoculum for the experiment was prepared by growing the various isolates from spore suspensions on sterile chopped hop bine in 500 ml. conical flasks at room temperature. The hop bine became thoroughly permeated by the fungus, and was ready for use in 7-10 days.

The experiment was set out between 23rd and 27th March, 1953. There were seven treatments, viz. inoculations with 6 different *Verticillium* isolates and uninoculated controls, and each consisted of 20 plants in 12-inch pots in 5 randomized blocks of 4 plants. Each 4-plant block was accommodated in one of the concrete tank units, the pots being bedded firmly in the sand. The plants used were first-year sets of Fuggle N hop, and for the inoculations about ½ oz. of the infected bine was incorporated in the potting compost immediately beneath the set at the time of planting. Two bines from each plant were trained vertically as shown in Fig. 1.

In order to ensure characteristic symptom development several applications of nitrogenous fertilizers were made, viz. dried blood on 28th May, fish meal on 12th June, and ammonium sulphate at the rate of ¼ oz. per pot in solution on 17th and 29th July and 13th August. The trial was also sprayed with 6 oz. magnesium sulphate in 2 gallons of water on 6th June, 7th July, 18th July, and 29th July to avoid simulation of Wilt symptoms by those of magnesium deficiency. Care was exercised in watering the pots to avoid cross-inoculation by splashing, and as a further precaution all dead leaves were collected and burned each day. A hessian (hop lewing) screen was erected to prevent infected material from blowing away to other plots. Symptom records were made at intervals from early June till the end of August.

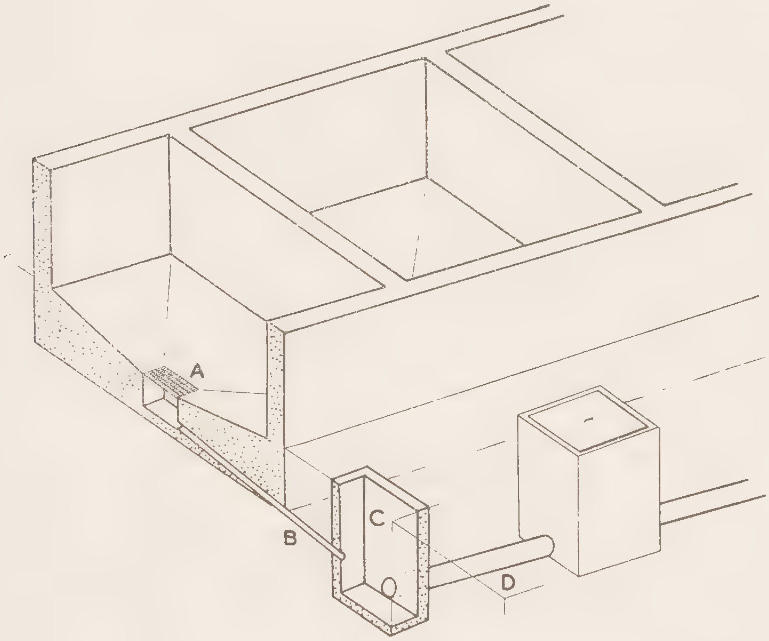

Fig. 2.
Sectional diagram of part of a four-unit tank.

Results.

Records were made of the intensity of leaf symptoms, height of bine, the rate of extension of symptoms up the bine, and the general appearance of the plants. By early July it was clear that the plants in the inoculated treatments could be classified into two groups, namely those showing (1) acute symptoms, with general yellowing and extensive marginal and interveinal necrosis of the leaves, stunting of the bine, defoliation, and ultimate death of the aerial parts of the plants, and (2) mild symptoms, sometimes in only one of the pair of bines, with some yellowing and sectorial necrosis of the leaves mostly in the lower part of the plant.

The uninoculated control plants showed no disease symptoms at this stage, but symptoms of senescence later appeared and were probably related to the method of culture. These symptoms resembled those of very mild Wilt, and were recorded as such, though there was no evidence that cross-inoculation between treatments had occurred.

Summaries of the symptom records taken in early July and late August are presented in Table I. In a practical application of the method the isolates 1, 2, 3, and 4 would be ' unknowns ', to be tested against standard progressive (P) and fluctuating (F) strains ; but for the purpose of testing the method each isolate used was of known pathogenicity.

TABLE I.

SYMPTOM CLASSIFICATION OF RECORDED BINES.

Isolate of pathogen.	8th July, 1953.				27th August, 1953.				Total no. of bines recorded.
	Acute symptoms.	Mild symptoms.	Apparently healthy.	Dead from other causes.	Acute symptoms.	Mild symptoms.	Apparently healthy.	Dead from other causes.	
1	38	—	—	—	38	—	—	—	38
2	2	35	3	—	1	36	—	3	40
3	2	37	1	—	2	37	—	1	40
4	37	2	—	—	37	2	—	—	39
P	36	3	—	—	37	2	—	—	39
F	3	29	4	3	2	27	—	10	39
Control (H)	1	3	36	—	—	40	—	—	40

It is apparent from this table that the results of the inoculation treatments can be divided into two groups : (*a*) treatments 1, 4, and P, resulting in acute symptoms, and (*b*) treatments 2, 3, and F, producing mild symptoms. The isolates of *Verticillium* in the first group were in fact originally obtained from known outbreaks of progressive Wilt, and those in the second group from characteristic fluctuating outbreaks.

It will further be noted that in treatment ' F ' a number of bines were killed. These bines died back from the tip, leaving the base apparently normal ; the symptoms did not resemble those of either progressive or fluctuating Wilt, and there was no evidence of the presence of any other pathogen. The cause of this necrosis is therefore unknown. In most instances a single bine was affected, while the second bine of the plant showed mild wilt.

Discussion.

The trial has indicated that hop plants grown and artificially infected with *Verticillium* under the conditions of the tank culture described show marked differences in symptom expression which are directly related to the form of the disease at the source from which the pathogen was isolated. The technique could therefore be used to determine the disease status of new Wilt outbreaks in areas where immediate and drastic control measures are desirable. Tests can now be made on isolates derived from ' intermediate ' or ' indeterminate ' outbreaks to ascertain whether they are environmental variants of the progressive or fluctuating types, or are an expression of further variation in the pathogen.

Summary.

The trial is described of a method for growing hop plants in concrete tanks to provide convenient test material for determining the pathogenicity of strains of *Verticillium albo-atrum* derived from Wilt outbreaks.

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ENTOMOLOGY

NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1953

By A. M. MASSEE

1. Strawberry Blossom Weevil (*Anthonomus rubi* Herbst).

The Strawberry Blossom Weevil has not been regarded as a serious pest in Kent for many years, but from time to time infestations have been noted in strawberry fields in the King's Wood district and in the area around Westerham and Toy's Hill.

This weevil was prevalent in several strawberry fields in the East Malling district during the latter half of May and early June, and in one about thirty per cent of the blossoms were damaged. Infestations were also noted at Plaxtol and at Sevenoaks ; it would appear that the weevil was widespread and common in many parts of Kent. It appears to be more partial to Royal Sovereign than to other commercial varieties, but Auchincruive Climax was also affected to a lesser extent.

The application of one or more DDT dusts (5 per cent) will prevent the weevils destroying the blossom trusses, but it is essential to keep a constant watch for the pest from the latter part of April onwards, and to apply the dust directly the first sign of blossom injury is noticed.

2. Imported Ground Beetle (*Somotrichus unifasciatus* Dejani).

A consignment of brazil and other nuts contained in sacks were sent to apple packing premises at Faversham for storage. In November a small, very active, and prettily marked ground beetle was seen in considerable numbers running amongst the sacks in the store. The Management of the Packing Station was naturally concerned by the presence of the beetles, and enquired whether they were likely to become established and cause damage to nuts or fruits being housed in the store. The species proved to be an imported ground beetle, a native of Algeria. It belongs to the family *Carabidae*, and it is known by the scientific name of *Somotrichus unifasciatus* Dejani.

This species was also found at Cardiff and London docks during the same week, under circumstances similar to those noted at Faversham ; it is suggested that all were imported with one consignment of brazil nuts from abroad. A number of the beetles were kept in captivity and were found to be carnivorous in their tastes. They fed readily on small flies and minute lepidopterous larvae, and were not interested in various species of nuts, slices of apple, or other delicacies offered them. Many of the species closely allied to *Somotrichus* are predacious in their habits, and it is most unlikely that the imported ground beetle will damage produce in store.

The writer is indebted to Mr. P. G. Clark for bringing this interesting species to his notice, and to Mr. E. B. Britton, of the British Museum, for checking the determination of the species.

3. Apple Clearwing (*Aegeria myopaeformis* Bork.).

Reports concerning attacks of the larvae of the Apple Clearwing have been received from the Wisbech district, and from the Rochester area of Kent. Newton Wonder appears to be more subject to attack than other sorts, but Allington Pippin, Bramley's Seedling, Early Victoria, and Worcester Pearmain are also affected.

The injury caused by the larvae is mainly confined to the trunks and larger branches, and the younger growth is rarely affected. The feeding is confined to the inner layers of the bark and associated tissues, and the heart wood is never attacked. Canker often follows the initial insect infestation, and much harm may be caused to the trees.

Another small moth, popularly known as the Cherry-bark Tortrix Moth (*Enarmonia formosana* Scop.), enjoys similar feeding sites, and it is frequently found infesting the same parts of the trunk as the Apple Clearwing.

Some experts consider that both these bark-feeding species are attracted to trees already suffering from canker infections, but my own experience in Kent supports the view that apparently healthy trees may become infested by these two species of moths, and that canker follows in due course.

It should be noted that initial outbreaks of both Apple Clearwing and the Cherry-bark Tortrix Moth are usually confined to a few trees of the orchard, and that such outbreaks should be eradicated before the infestations become general.

4. Goat Moth (*Cossus cossus* L.).

' Cossus ' trees or in other words trees in old orchards whose trunks are infested with larvae of the Goat Moth are not very common, and attacks of this insect are usually confined to one or two trees, the favourite hosts being cherry and oak. The presence of the Goat Moth can be detected at once by the large and conspicuous galleries made by the larvae, and by the exudation of sap which seeps from the galleries and trickles down the tree trunk. The exudation of sap from the ' Cossus ' trees attracts many rare and interesting insects of many Orders, more especially some of the smaller species of Coleoptera, and several novel kinds were found in the spring months.

The Goat Moth was very common in an old eleven-acre orchard, of very mixed varieties, at Ulcombe, Kent. The larvae were still ' working ' in some of the trunks, and the more mature larvae were thought to be three or four years old. Apple, cherry, and walnut trees were infested, and it was evident that the insect had been established in the orchard for very many years.

The Goat Moth rarely occurs in well-kept orchards these days, but the old tree which may be infested should be destroyed.

5. Light Emerald Moth (*Metrocampa margaritaria* L.).

The Light Emerald was common in commercial orchards in the East Malling district during the winter of 1952-3, the small ' looper ' caterpillar being found feeding on the bark and buds on the young growths of newly planted apple trees.

The moth is whitish-green in colour, but soon fades when dead. It has a wing expanse of one and a half inches. It occurs most frequently in woodland districts, and is on the wing in June and July.

The moth lays her eggs in batches on the under surfaces of apple leaves in July and August. The minute larvae hatch out in a week or so, and disperse to the main shoots where they remain throughout the winter. The feeding is confined to the outer layers of the bark during the winter, and the apical portions of the shoots are preferred to the stouter wood. The removal of the bark exposes pale areas near the tips of the shoots which are readily ' spotted ' by pruners. The larvae feed during March and April, mainly on the buds, but some bark is still taken.

The larvae feed in all weather conditions ; they are commonly found stretched out quite rigid and flat against the stem during the periods they are not feeding. They vary in colour from a green-brown to purple-brown, and when fully fed attain a length of one inch or more. It has many other hosts in addition to cultivated fruits, the chief being beech, birch, elm, and oak.

6. Clouded Drab (*Orthosia incerta* Hufn.).

The Clouded Drab has been a minor pest of the apple orchard for many years, and in common with many other fruit insects, the importance of the injury caused by it varies from season to season. In 1953 it was much more prevalent than usual in the Maidstone and West Malling districts of Kent.

The moth occurs on the wing in April and May, and eggs are laid on the leaves and shoots of apple from the pink bud stage to petal-fall. This species also occurs commonly in woodland districts, and it is very partial to sallow blossom. The minute, green larvae feed on the surface of apple fruitlets as soon as they are formed, thus large numbers of fruitlets may be damaged in seasons when the insect is plentiful. It causes much harm by gnawing out a small piece of flesh from one cheek of an apple fruitlet, and then moving on to another and repeating the operation. When fully fed the caterpillar is apple green, covered with minute whitish spots, and is ornamented with three white lines along the back, the central one being the widest. There is also a white stripe edged with black along each side. It is fully fed by the end of June, and the chrysalis stage is formed in the soil, where it remains until the following spring.

A number of other insects cause similar injury to the fruitlets as the Clouded Drab caterpillar.

7. Pith Moth (*Blastodacna atra* Haw.).

The Pith Moth has been a persistent pest in apple orchards and gardens for many years and is generally distributed in Essex, Kent, and Sussex. It was abnormally common in commercial apple plantations in Essex in 1952 and again the following year, and in fact it has been prevalent throughout the fruitgrowing districts of the country.

The Pith Moth is minute, with blackish or dark brown wings and a wing expanse of about 10 mm. It is on the wing in July, and lays its eggs singly on the leaf axils and near the base of the buds, in the latter part of the month and the first half of August. On emergence the reddish-brown larvae tunnel into the bark, the stem tissue, or more frequently at a point adjacent to a fruit bud. In the spring months the careful observer will be able to trace where the larva is 'working' in the tissue, by the presence of a small quantity of frass, deposited by the larva at the entrance hole of the gallery. The nature of the injury made by this pest is much more conspicuous during the latter part of April and May, than at other periods of the year, so naturally this is the time when fruitgrowers notice the pest on their trees.

The symptoms of attack are the wilting or withering of the leaves on the tips of the shoots in which the larvae are feeding ; when the fruit bud is killed by the larva tunnelling inside, the rosette leaves of the trees wilt and die. The removal of such buds will reveal the dark brown larva, with shining black head, inside.

The routine spray programme does not eradicate this pest, and in orchards where the Pith Moth presents a problem it may be necessary to apply an insecticide at the end of July to prevent the newly-hatched larvae penetrating the stem tissue and buds.

8. Cherry Fruit Moth (*Argyresthia curvella* L.).

Severe infestations of the Cherry Fruit Moth have been noted at Key Street, Sittingbourne, Faversham, and in the neighbouring districts. This pest is generally distributed, occurring in cherry orchards at Allington, Brenchley, Canterbury, Chartham, Cuxton, East Malling, East Sutton, Kingsdown, Offham, Plaxtol, Sevenoaks, Tenterden, Tonbridge, and West Farleigh. It is found in orchards which receive a 5 per cent tar oil wash annually, and also in those which have not been winter sprayed for a number of years. A wide range of varieties are subject to attack, including the following : Early Rivers, Black Circassian, Early Amber, Governor Wood, Bigarreau de Schrecken, also Emperor Alexander and Guigne d'Annonay.

The Cherry Fruit Moth has not been very common in Kent until recently, although it was noted in orchards at Kingsdown and Chartham some thirty years ago. It is not known why it has become so common in recent years, but many other fruit insects fluctuate in numbers over the years.

The larval stage of the Cherry Fruit Moth bores into the fruitlets, in a manner similar to the Codling Moth of apple. Indeed, the Cherry Fruit Moth might well be described as the 'Codling Moth' of cherry. The infested fruitlets may be found in the orchard a few days after petal-fall, when the fruitlets are beginning to swell. The entry hole (surrounded by a small black area) is made in the flesh of the fruitlets, and the inside is eaten away. When the fruitlets are very small it is necessary to remove the sheath in order to find the entry hole. The larvae may be found in the fruitlets from the latter part of April until the third week of May. The fully fed larvae drop from the trees by a fine silken thread, and pupate in the soil in an earthen cocoon. Larvae were not found in the fruits after 23rd May.

The moth has a wing expanse of about half an inch. The fore-wings are light brown, with a white line along the lower border, and an oblique brown streak reaching to the tip of the wing. The hind wings are grey with a fringe of conspicuous hairs around the border. The moth may be found in the orchard from the third week of June until the third week of August.

The egg is pale fawn to light grey, it is reticulated and has a distinct ring of micropyles at one pole. It is one and a quarter mm. long. The egg is extremely difficult to find in the field because the colour blends so well with its immediate surroundings. The eggs are laid singly or in pairs at the base of the buds, in cracks, crevices, and wounds on the shoots and branches.

The Cherry Fruit Moth mainly overwinters in the egg state. Some of the eggs hatch in the autumn, and the first or second instar larvae overwinter on the trees encased in a small silken cocoon. The eggs hatch in the latter part of March and in April, and bore into flower buds before they expand. The overwintering larvae also enter the flower buds about the same period.

Experiments some years ago suggest that a tar oil wash, applied at 8 per cent in December, will kill the eggs, but the winter wash is not effective against the overwintering larvae. It is suggested, therefore, that a DDT emulsion be applied at the end of March to kill the larvae before they penetrate the buds.

9. Strawberry Tortrix Moth (*Argyrotoza comariana* Zell.).

Two small outbreaks of this moth were noticed in established strawberry fields at East Malling and a third at Sevenoaks during June. In each case the variety infested was Royal Sovereign ; other sorts growing nearby were not attacked. This strawberry pest does not often cause much harm in Kent, but it is more plentiful farther north, and sometimes presents a very serious problem in the Wisbech area. The insect overwinters as an egg on the plants. The larvae hatch out at the end of

March and in April and feed on the leaves before they unfold. Later they feed on the unopened flowers, particularly the stamens and developing carpels, so either destroying or distorting the fruits.

There are two generations of the Strawberry Tortrix Moth a year, but curiously only the first generation was noted in Kent in 1953. This was fortunate, because the second generation is considered to be the more serious.

The Strawberry Tortrix Moth was last referred to in these notes in 1943.

10. Dock Sawfly (*Ametastegia glabrata* Fall.).

The Dock Sawfly may be regarded as a ' nuisance ' pest because the larvae of the third generation tunnel into the flesh of the apples just prior to picking time, and disfigure many of the fruits and allow of the entry of Brown Rot. It was very common in several orchards in the Maidstone district and caused considerable damage ; another report came from Chelmsford, Essex, in late August. The prevalence of this species in apple orchards is frequently difficult to account for. The usual host plant of the Dock Sawfly is the common field dock, but infestations are often noted in apple orchards where docks do not grow in sufficient numbers to support large numbers of larvae. It is therefore interesting to record the larvae feeding on the foliage and flower heads of fat hen growing abundantly in an apple orchard at Allington. It is possible that certain strains or races of the larvae are more partial to fat hen than dock, but whatever the true explanation is, the grower is advised to be on the alert for this insect in the autumn before they infest the fruits, especially where the growth of autumn weeds, in which fat hen is common, follows on clean cultivation in spring and summer.

11. Pear Sawfly (*Hoplocampa brevis* Klug).

It seems likely that the Pear Sawfly is more widely distributed in Kent than is generally supposed. A new habitat for this insect was noted at the end of May. It occurred in a young pear plantation at Upchurch, where the chief varieties infested were Conference and Fertility.

The attack was not very serious, but the presence of the pest in this corner of Kent is rather disquieting, because it has been successfully eradicated from certain plantations in the Rochester district, where it was found a few years ago. It is not known how long the Pear Sawfly has been present in the pear plantations at Upchurch, but the old farm workers and others connected with horticulture in the district declare that ' maggoty ' pears have been found regularly each season for many years past. Whether the ' maggoty ' pear statement refers to the Pear Sawfly or not is purely speculation, but the fact that Pear Midge (another fruit-infesting species) also occurs in the same district leaves good reason for doubt. Fruitgrowers in the Upchurch district are strongly advised to examine their pear plantations carefully just after petal-fall and determine whether the pest is present. The larva bores into the cheek of the pear fruitlet, and the entrance hole made by the larva is very conspicuous.

The writer is indebted to Mr. T. Laflin, Horticultural Officer for Kent, for bringing this insect to his notice.

12. Black Currant Sawfly (*Nematus olfaciens* Ben.).

The Black Currant Sawfly has undoubtedly been established in black currant plantations for many years, and has been regarded as the same species as that associated with gooseberry. Recently, however, Mr. R. B. Benson of the British Museum has found it to be a distinct species, and recently described it as a new British insect. The fact that the Black Currant Sawfly feeds only on black currant, and will not survive on related hosts, shows a difference in habit from the gooseberry species.

A serious infestation of the Black Currant Sawfly occurred on a large field of black currants during the last two seasons in North Essex. Other small attacks in the same district have also been reported. The sawfly has also been recorded from Gloucestershire and Scotland. There is little doubt that this species was seen infesting black currants in several localities of Kent during 1940 and 1941, when the Fruit Survey was being made, but at that time the species was considered to be the Gooseberry Sawfly, and was recorded as such.

The larva feeds on the foliage in a similar manner as the gooseberry species, starting low down in the centre of the bush, and working outwards, but the damage caused by the currant species is not as extensive as that made by the larvae of the Gooseberry Sawfly. Material bred in captivity produced two generations a year, but at present details of the life-cycle are unknown.

13. Shield Bug (*Sehirus bicolor* L.).

The presence of the black and white Shield Bug on apple is worthy of mention, since it confirms earlier records of the occurrence of this insect on fruit.

Two egg batches of the bug were noted on the undersides of apple leaves, in different orchards, at East Malling, in June. Early in July another egg batch was found, also on apple foliage, at Cranbrook. Two of the egg batches hatched in July, but the nymphs could not be induced to feed on apple foliage in captivity, but when transferred to Dead Nettle they fed normally, and many were reared to the adult state.

The fact that this species of shield bug sometimes lays its egg batches on the leaves of apple, plum, and raspberry must be considered most unusual, and no reasonable explanation seems to be forthcoming. The normal host plants of this insect are Stinging Nettle, Dead Nettle, Woundwort, and related plants. The nymphs prefer to feed on the flower heads of these plants and the bugs are gregarious. The eggs are said to be laid in small holes in the ground in May and June, and the female sits on the eggs until they hatch. The latter point is of considerable interest, because when the egg batches are found on apple leaves, the adult is invariably in attendance.

14. Pear Leaf Midge (*Dasyneura pyri* Bouché).

The Pear Leaf Midge is widespread throughout England, periodically causes considerable harm to the tender new growths of pear by severely distorting the foliage. This minor pest is particularly troublesome in the nursery and to young trees. It was exceptionally common in the nursery in the years 1920-21 in the Maidstone district, and since that period small outbreaks have been noted in some seasons. It proved to be very prevalent again in 1952-3 in many parts of Kent and Essex, causing weak growth and malformed foliage. The varieties Conference, Fertility, and Williams are very susceptible, but most sorts grown commercially suffer to some degree.

This midge produces at least four generations a year. The first flight of midges occurs in late April, and the populations increase through successive generations until a peak is reached in August and September, when much harm may be caused to the trees.

In the nursery beds and young plantations where this pest occurs each season, control will be obtained by spraying with a DDT emulsion (15 per cent) at the rate of three pints to the hundred gallons water. The application should be made at the white bud stage, just before the flowers open. The object of the spray is to kill the midges of the first generation when they visit the trees to oviposit their eggs on the newly-opened and as yet unfolded leaves. Once this insect has been eradicated from a pear plantation, it requires a number of years to build up its populations again, and by this time the trees will probably be too well established to suffer very much harm.

15. Hop-Damson Aphid (*Phorodon humuli* Schr.).

The Hop-Damson Aphid proved very troublesome in many districts of Kent, especially the Weald, owing to the very prolonged migration period. The winged forms began to migrate from sloe from the hedgerows about the third week of May—the normal period—but the migration extended over a very long period, and in fact it was not complete until the third week of July.

In practice when parathion or the systemic insecticide Schradan are being applied, two applications are normally sufficient. The first should be made early in June, being followed by a similar spray some three weeks later. But when the migration period extends into July further applications are necessary. In seasons when the aphid is still prevalent at the end of July insecticides with a lower residual toxicity must be used. For example, during or after the ‘ burr ’ stage TEPP is recommended against both the Hop-Damson Aphid and the Red Spider Mite.

16. Oat-Apple Aphid (*Rhopalosiphum insertum* Wlk.).

The Oat-Apple Aphid has caused much concern to fruitgrowers in many parts of Kent, and small infestations have been noted in orchards at Canterbury, Maidstone, Mereworth, Plaxtol, and Southfleet. Other infestations were noted at East Grinstead and Icklesham, Sussex.

Fruitgrowers have been worried on finding small colonies of the Oat-Apple Aphid in their orchard during and just after the blossom period, more particularly in orchards where the routine winter washes, and the delayed dormancy sprays, have been omitted, and spring and summer sprays have been relied upon to control the major pests, including the fruit aphids. In practice it seems likely that DDT and BHC, when used at the green cluster stage to control aphids, do not give quite as good control as tar oil or DNC, but even so the kill is adequate to give a commercial control. In any event the grower need not become unduly alarmed on finding small colonies of the Oat-Apple Aphid on his trees after the blossom period, because at this season the aphid produces winged forms, and migrates to grasses and other hosts for the summer months.

It is essential that the grower should be able to recognize the various species of aphids which occur on apple, and to enable him to do just this, a popular article appears on page 213 of this Report setting out a simple key to the various species.

It seems likely that the various species of fruit aphids will remain a problem to the grower however modified the spray programme may become, the reasons being the aphids breed with great rapidity, there are many generations each year, and the complication of alternative wild host plants adds to the difficulty with some species.

17. Plum Leaf Mite (*Phyllocoptes fockeui* Nal.).

The Plum Leaf Mite is a very common species, and it is widely distributed in the British Isles. It feeds on the foliage of plum, gage, and damson, but the species is rarely seen because even the adult is not visible to the naked eye. It is closely related to the gall mite of black currant, but while the currant species causes a ' Big Bud ' the Plum Leaf Mite feeds freely on the leaf under-surface, producing small, white, hairy patches which are not very conspicuous.

A very severe infestation of the Plum Leaf Mite was reported from Colchester the third week of July. The mite was infesting various species of Prunus, and the injury caused to the foliage was very striking. Severe leaf-curl was noted on all the affected plants—the injury being similar to that caused by the Leaf-curling Plum Aphid. It was not possible to estimate the number of mites responsible for the damage, but the total was very large indeed.

Summary.

Short notes are given of some of the interesting insects and mites met with in 1953. Amongst the more important are the Strawberry Blossom Weevil, the Imported Ground Beetle (*Somotrichus unifasciatus* Dejani), the Cherry Fruit Moth, the Strawberry Tortrix Moth, Dock Sawfly, Black Currant Sawfly and the Plum Leaf Mite.

THE HOST PLANT RANGE AND ECONOMIC IMPORTANCE OF A GROUP OF GALL MIDGES *(THOMASINIANA* SPP.*)* ASSOCIATED WITH FRUIT

By R. S. PITCHER

The gall midges of the genus *Thomasiniana* Strand, occurring on Rosaceous plants, form a group whose members are not readily separable on morphological grounds. However, Barnes (1931, 1939, and 1944) has shown that they can be readily distinguished on the basis of their preferred host plant. The writer has elaborated Barnes's techniques and has applied them to the following members of the genus :

The Raspberry Cane Midge (*T. theobaldi* Barnes), whose larvae live under the peeling bark of raspberry canes and in so doing render them liable to fungal invasion (Pitcher and Webb, 1952).

The Red Bud Borer (*T. oculiperda* (Rübs)), a pest of newly-budded rose and fruit tree rootstocks, which its larvae damage by feeding on the cambial layers of stock and scion (Barnes, 1931). Midges of this species bred from apple and rose have been tested separately.

The Hawthorn Stem Midge (*T. crataegi* Barnes), whose larvae damage the cambium of hawthorn, often causing die-back of shoots (Barnes, 1939).

An unnamed *Thomasiniana* sp. from wild blackberry canes, originally found at Wisley by Fox Wilson (Fox Wilson and Green, 1944) and believed at the time to be *T. theobaldi.*

The results given below make it possible to define more critically both the specific and the economic status of each member of this group.

Host plant preference trials.

The technique of these tests, developed during work on the Raspberry Cane Midge, has been described in detail elsewhere (Pitcher, 1952). There were minor variations in procedure from test to test but all contained two estimations of preference, the first relating to the adult midges and the other to the larvae. Firstly, oviposition preferences were tested by allowing free-flying midges equal opportunity to lay eggs on artificially slit shoots of any of the host plants offered. An estimate of the relative acceptability of each plant was made by counting the number of eggs laid after two to three days. The shoots were then kept in water for a further two to three weeks, after which counts of nearly-mature larvae were made to assess the suitability of each host plant for larval development. It was found that midges would often lay eggs quite readily on plants which were unsuitable for larval development. This lack of discrimination is curious, but it is clear that it is the larval figures which give the best estimate of the suitability of a host plant for the propagation of the species under test.

In the majority of the trials apple (rootstock M.IX), wild blackberry, raspberry (Malling Enterprise), rose (briar rootstock) and, sometimes, hawthorn were used as the basic test plants. A summary of the means of these results, expressed as a percentage of the numbers of eggs or larvae on the original host plant, is given in Table I. From time to time loganberry, cultivated blackberry, blackthorn, and various fruit tree rootstocks were also included ; the results of these supplementary tests are given in the following paragraph.

T. theobaldi, although clearly preferring raspberry, laid eggs on many other hosts, of which only rose would support the larvae ; the complete failure of blackberry was rather unexpected. Of the other hosts tested only loganberry and Himalaya blackberry supported larvae, the former being the equal of raspberry. The *Thomasiniana* sp. from wild blackberry resembled *T. theobaldi* in its non-selective oviposition and in its ability to raise a few larvae on rose. On *Rubus* spp., in contrast to *T. theobaldi*, it showed a marked preference for blackberry, on which it laid more eggs and raised many more larvae than on raspberry. Loganberry was included in two of the trials but, although some eggs were laid on it, no larvae reached maturity. *T. oculiperda* from apple showed a preference for apple for oviposition but would lay eggs on many other species, including blackthorn, cherry, peach, pear and plum. The genus *Rubus* seemed to exert no consistent attraction although eggs were laid on it from time to time. Larvae survived readily on apple, occasionally on rose and, on the one occasion on which it was tested, on blackthorn. The *T. oculiperda* from rose, while resembling those from apple in their neglect of *Rubus* spp., showed no significant oviposition preference for rose and on two occasions laid more eggs on apple. The larvae, too, were quite tolerant of apple, only once completely failing to survive. Thus, although retaining a certain preference for their original host, the *T. oculiperda* from rose appeared to be more flexible than those from apple. In addition to the tabulated hosts, blackthorn, plum and cherry were offered to *T. crataegi* but no eggs were laid on them.

TABLE I.

HOST PLANT PREFERENCE TRIALS OF *Thomasiniana* SPP.—MEANS, EXPRESSED AS PERCENTAGE OF THAT ON THE ORIGINAL HOST PLANT.

No. of trials.	Species tested.	Apple.	Blackberry.	Raspberry.	Rose.	Hawthorn.
				Eggs.		
4	*T. theobaldi*	12	48	100	46	1·8
4	*Thomasiniana* sp. from wild blackberry	3·8	100	9·5	10	—
7	*T. oculiperda* from apple	100	0·7	0·3	4·4	0·9
3	*T. oculiperda* from rose	122	1·2	0	100	—
2	*T. crataegi*	0	0	0	0	100
				Larvae.		
3	*T. theobaldi*	0	0	100	25	0
6	*Thomasiniana* sp. from wild black berry	0	100	0·3	0·8	—
7	*T. oculiperda* from apple	100	0	0	0·8	0
5	*T. oculiperda* from rose	21	0	0	100	—
2	*T. crataegi*	0	0	0	0	100

Discussion.

On host plant preference grounds it seems that *T. crataegi* is quite distinct from the other species considered. Careful morphological examination has revealed several small points, notably the larger size of adults and larvae, the paler pink colour of the mature larvae and certain differences in the length of abdominal setae which support this conclusion.

The remainder, all of which tolerate rose to a greater or lesser extent, can be fairly readily divided into the *Rubus*-favouring *T. theobaldi* and the *Thomasiniana* sp. from blackberry on the one hand and the *T. oculiperda* from apple and rose on the other. The host plant preferences of *T. theobaldi* and the midge from blackberry differed so strikingly that it seemed possible that there was a specific difference between them. The only morphological characters supporting this theory were, firstly, a colour difference between the larvae, those of *T. theobaldi* being of two distinct colours (pink and orange) while those of the *Thomasiniana* sp. from blackberry were all pink and, secondly, the more prominent elongation of the terminal segment of the male antenna in the midge from blackberry. It was therefore necessary to carry out cross-breeding tests to clarify the position. Twenty cross-matings were attempted but none yielded eggs, whereas it is usual for at least 50 per cent to do so in comparable self-matings. It was therefore concluded that the midge from blackberry was not a variety of *T. theobaldi* but was, in fact, a new species. A formal description, together with the proposed specific name, will be given in a forthcoming paper, which will also contain a fuller account of the biological and morphological contrasts within this group (Pitcher, 1955). It is proposed to adopt the common name of Blackberry Cane Midge for this species.

The host plant preferences of the Red Bud Borers from apple and from rose do not differ as markedly as those of the Raspberry and Blackberry Cane Midges and there are no larval colour differences, although the abdominal setae show certain contrasts. It is considered, however, that there is ample evidence for the recognition of two strains within the species which will be referred to in future as the apple and rose strains of *T. oculiperda*.

When considering the group as a whole *T. crataegi* immediately stands out as distinct both by its neglect of rose and on morphological grounds. The ability of all the other members of the group to live, with varying success, on rose suggests that they may all have arisen as offshoots of the rose strain of *T. oculiperda*, a possibility which is supported by the marked adaptability shown by this strain in the host plant preference trials.

Economic importance.

Although the Hawthorn Stem Midge (*T. crataegi*) is widely distributed in south-east England and the Midlands it has never been known to injure hawthorn sufficiently to affect its usefulness as a hedging plant. *T. oculiperda*, the Red Bud Borer, has been shown to contain biologic strains from apple and rose, both of which can live to some extent on either host and can thus cause injury to the budded rootstocks of either. The writer has often found large colonies of each strain living as casual inhabitants of broken branches of established apple trees or of hedgerow roses respectively. It is likely that these sites form reservoirs of infestation whence come most of the midges of the summer generation which from time to time cause extensive damage to newly budded fruit-tree and rose rootstocks. It would therefore seem prudent to site nurseries as far away as possible from established apple orchards and to exclude rose from neighbouring hedges. Both the Raspberry and Blackberry Cane Midges could also cause some damage to rose, but this is not likely to be serious. Raspberry is the only host of economic importance of the Raspberry Cane Midge (*T. theobaldi*) and serious damage will occur only on varieties whose bark readily splits and peels. Loganberry and Himalaya blackberry may harbour a few larvae, chiefly in broken canes, but no important damage is likely. The Blackberry Cane Midge lives almost exclusively on hedgerow blackberries. Cultivated blackberries may occasionally be attacked but no economic damage is likely as the bark of blackberry does not split extensively, so that larval colonies will be largely confined to broken canes. Raspberries may be lightly attacked if grown in the presence of many wild blackberries.

Acknowledgements.

The writer wishes to thank Dr. H. F. Barnes of Rothamsted Experimental Station for his valued help and advice.

Summary.

A comparison is made of all the members of the genus *Thomasiniana* Strand at present known from Rosaceous host plants, namely *T. oculiperda* (Rübs.), the Red Bud Borer ; *T. theobaldi* Barnes, the Raspberry Cane Midge ; *T. crataegi* Barnes, the Hawthorn Stem Midge, and a hitherto undescribed species from wild blackberry. Although morphologically very similar, each can be readily distinguished in host plant preference trials. By this means it has also been shown that there are two strains, favouring apple and rose respectively, within the present species *T. oculiperda*. The biological and economic status of each species or strain is discussed.

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PLANT PROTECTIVE CHEMISTRY

THE FRUIT TREE RED SPIDER MITE, *METATETRANYCHUS ULMI* (KOCH): PILOT TRIALS IN THE FIELD OF SOME NEW OVICIDES ACTIVE AGAINST WINTER EGGS

By A. H. M. KIRBY, R. P. TEW, and R. G. GAMBRILL

In the past, control of winter eggs of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), has been attempted with reasonable success by sprays containing 3 per cent of a suitable grade of petroleum oil. It proved advisable to apply this oil as late in the winter as possible but this led to damage to buds in certain areas. Alternative chemicals for control of these eggs have therefore been sought. These fall into two classes : (*a*) true winter ovicides, i.e. for application up to bud-burst ; and (*b*) ovicides which could be applied between bud-burst and completion of egg-hatch. This paper therefore falls naturally into these two divisions.

Experiments with a winter ovicide, dinoseb.

Laboratory tests.

A commercial sample of dinoseb (4 : 6-dinitro-2-*sec*-butylphenol), formulated as the triethanolamine salt, was available for tests in the winter of 1949-50. Analysis by the standard method for ovicides based on DNC showed the content of dinoseb to be 22·5 per cent. Suitable lengths of shoots bearing winter eggs were dipped in aqueous dilutions of the formulated product on 1st March ; the percentage hatch was determined in the following summer in the usual way (Eaton and Davies, 1950). Mortalities of 100 per cent were obtained with dinoseb concentrations of 0·225 and 0·115 per cent, and of 90 per cent at 0·06 per cent. A further test was carried out on 8th March, 1951, eggs laid on Worcester Pearmain seedlings in a greenhouse in the previous autumn being used. Lower concentrations of dinoseb were employed, namely 0·06, 0·03, and 0·015 per cent. The mortalities were 92·5, 44·8, and 25·5 per cent respectively, indicating an LD_{50} value in the region of 0·026 per cent, and an LD_{95} value of about 0·085 per cent.

Field tests.

1951 Trial.—As complete kill had been achieved in the laboratory, using dinoseb at 0·1 per cent a field trial was carried out at East Malling using the commercial amine salt preparation at 0·5 per cent v/v, i.e. 0·113 per cent dinoseb. A second treatment consisted of the same preparation at 0·75 per cent v/v, i.e. 0·17 per cent dinoseb. Two further treatments were designed to investigate the effects of adding a wetting agent and, in view of the water-soluble nature of the dinoseb formulation, an added sticker of the polyethylene polysulphide (PEPS) type. A standard DNC-petroleum oil treatment was also included, and a few trees were left as unsprayed controls. The seven treatments are listed below :

1.	DNC ..	0·08 per cent w/v
	Petroleum oil	3·4 per cent v/v
2.	Dinoseb triethanolamine salt*	0·5 per cent v/v
3.	Dinoseb triethanolamine salt*	0·75 per cent v/v
4.	Dinoseb triethanolamine salt*	0·5 per cent v/v
	Wetting agent A ..	0·05 per cent v/v
5.	Dinoseb triethanolamine salt*	0·5 per cent v/v
	Wetting agent B ..	0·01 per cent w/v
6.	Dinoseb triethanolamine salt*	0·5 per cent v/v
	Wetting agent B ..	0·01 per cent w/v
	Polyethylene polysulphide (moist preparation)	0·05 per cent w/v
7.	Untreated controls.	

* 36 per cent solution.

Wetting agent A was an aqueous solution of a non-ionic surfactant of the ethylene oxide condensate type.

Wetting agent B was pure di-octyl sodium sulphosuccinate.

Five replicates of these treatments were applied to a row of Worcester Pearmain apple trees on M.IX stocks running north and south, after a category record of winter eggs had been taken, on 21st February. The weather was dry and sunny, so that sprays dried quickly ; the wind was moderate, but, being westerly, caused no drifting within the experimental row. Rather less than two gallons of wash was used per tree ; treatments 1, 4, 5 and 6 wetted the trees very well, but 2 and 3 were rather less efficient in this respect. A pressure of 300-350 lb. per sq. in. was maintained.

An imprint record of the mites present was taken on 11th June, when the hatching of winter eggs was complete, using eight leaves from each tree. The data thus obtained were related to the original winter egg populations by an analysis of covariance and the following figures obtained by retransforming to numbers of mites ; figures in brackets do not differ significantly ($P = 0 \cdot 05$).

Treatment	6	1	4	5	3	2	7
No. of mites per leaf	3·6	14	22	30	35	70	79

The egg-hatch following treatment 2 was not significantly different from that on untreated controls. Treatment 6, dinoseb plus wetting agent plus sticker, gave a significantly greater reduction of hatch as compared with all other treatments, including the standard DNC-petroleum.

Treatment 4, dinoseb 0·113 per cent plus wetting agent A, was as effective as DNC-petroleum, and treatment 5, dinoseb 0·113 per cent plus wetting agent B, was not significantly poorer than treatment 4. Both treatments 4 and 5 were at least as effective as treatment 3, dinoseb at the higher percentage, 0·17 per cent. Thus the inclusion of a suitable wetting agent increased the efficiency of dinoseb as an ovicide, making 0·113 per cent as efficient as 0·17 per cent used alone. This effect, combined with the retention due to the sticker (treatment 6) led to a very substantial improvement in the performance of this ovicide ; there was no evidence of any damage to the trees, phytotoxic effects throughout the trial being negligible.

1952 Trial.—A similar trial to that carried out in 1951 was done on the same trees in 1952. The winter-egg infestation was light throughout the row and was regarded as even for experimental purposes.

In view of the success achieved in 1951 with the treatment which included a sticker, the main object was to study the influence of stickers, in the presence or absence of a wetting agent, upon the control afforded by dinoseb. Two types of sticker were used : (*a*) the same polyethylene polysulphide preparation used in 1951 ; (*b*) a commercial calcium caseinate preparation. A stock solution of dinoseb was prepared by mixing 382 grams dinoseb with 238 grams triethanolamine and diluted with water to 1,650 ml. ; tarry material separated at both stages and was removed by filtration through glass-wool. The filtrate had a specific gravity of 1·09 at 16° C., and analysis by the DNC method indicated 17·7 per cent phenol. 283 ml. of this concentrate was diluted in the spray-tank to a final volume of 12·5 gallons, giving a dinoseb content in the wash used of approximately 0·09 per cent.

The following treatments were applied to one-tree plots, replication being six-fold :

1. Dinoseb triethanolamine salt, 0·09 per cent dinoseb, w/v.
2. As treatment 1 plus PEPS, 0·05 per cent, w/v.
3. As treatment 1 plus calcium caseinate, 0·25 per cent, w/v.
4. As treatment 2 plus di-octyl sodium sulphosuccinate, 0·01 per cent, w/v.
5. As treatment 3 plus di-octyl sodium sulphosuccinate, 0·01 per cent, w/v.
6. Untreated controls.

Applications were made on 10th March, with a lance and a pressure of 350-400 lb. per sq. in., using approximately 2 gallons of wash per tree. The weather was overcast, with a light westerly wind so that drift was not a problem.

An imprint record of hatched mites was taken on 27th May, taking eight leaves from each tree. The figures reflected the low winter-egg density, and a significant difference was only obtained with respect to the effect of calcium caseinate. Where treatments 1, 2 and 4 had been applied, the mite population was halved, that is dinoseb was giving some reduction when applied alone or in conjunction with PEPS, with or without a wetting agent. But the average mite population per tree for treatment 5 was virtually identical with that for the unsprayed controls, while in the case of treatment 3 it was higher by two-thirds. The effect of PEPS was significantly better than that of calcium caseinate ($P = 0 \cdot 01$).

It would thus appear that, while the addition of PEPS or of PEPS plus wetting agent failed to increase the control afforded by dinoseb alone at the low level of infestation present on this occasion, the addition of calcium caseinate reduced the control afforded by the same ovicide and tended to obscure any benefit derived from adding a wetting agent.

Conclusions.

It is clear that dinoseb is toxic to the winter egg of the Fruit Tree Red Spider Mite and that substantial control can be obtained in the field if sufficient wetting agent and sticker be added. But it is unlikely that it can be used economically in all seasons, and seems to offer insufficient advantage over the well-established DNC-petroleum winter washes. This seems to be in line with the results reported by Chapman and his co-workers at the New York State Experiment Station. Chapman and Pearce (1949) reported that the triethanolamine salt of dinoseb at 0·5 per cent v/v alone or at 0·25 per cent plus 1 per cent oil gave good control, and, as it was also effective against aphis eggs, was recommended as a routine winter wash for that State. Similar success was obtained in the following season by Chapman and Lienk (1950) who reported, however, that build-up in the summer was faster on dinoseb plots than on petroleum oil (2 per cent) plots. But Lienk and Chapman (1951) found that dinoseb was much less effective in a third season, even at double strength.

Experiments with chlorinated phenyl benzenesulphonates for application at green cluster stage and later.

Laboratory experiments in 1951 and 1952 established that certain chlorinated phenyl benzenesulphonates were highly toxic at not less than 0·1 per cent to the winter eggs as well as the summer eggs of the Fruit Tree Red Spider Mite ; these results have been reported (Kirby and Tew, 1953). Meantime, Lienk, Chapman, and Myburgh (1952) in New York State had tried in 1951 applications of 4-chlorphenyl 4-chlorbenzenesulphonate (CPCBS) at 0·075 per cent at pink-bud, 12th May ; on 20th June there were no mites present (13 mites per leaf on control trees) and even by 25th July the average was only 0·9 mites per leaf (87 mites per leaf on control trees). A pilot scale trial at the Research Station was therefore undertaken to examine the possibility of applications at green cluster of the three esters at present in commercial development, and of other two-stage treatments.

The three esters chosen were CPCBS, CPBS (4-chlorphenyl benzenesulphonate) and DCPBS (2,4-dichlorphenyl benzenesulphonate). CPCBS, purified by recrystallization from methanol, had a melting point of 80-81° C. CPBS had a melting point of 54-56° C. and was used without further purification. DCPBS was prepared in the laboratory from 2,4-dichlorophenol and benzenesulphonyl chloride ; after recrystallization from aqueous ethanol and from methanol, the melting point was 43-45° C.

The sample of DNC-petroleum contained 67·5 per cent neutral oil and was used at 4·5 per cent, giving an oil content, in the wash, of fully 3 per cent.

The treatments and the stages at which they were applied are set out below :

	Treatment.	Concentration.	Stage of Growth.
A.	CPBS	0·1%	Green cluster
B.	CPCBS	0·1%	do.
C.	DCPBS	0·1%	do.
D.	CPBS	0·2%	do.
E.	CPBS	0·05%	Green cluster and Pink bud
F.	CPBS	0·05%	Pink bud and Petal-fall
G.	DNC-petroleum	3% oil	Bud-burst
H.	Unsprayed controls.		

The same row of Worcester Pearmain trees was used as for the dinoseb trials, and five replicates of the eight treatments were used. A heavy infestation of winter eggs was present throughout the row and was regarded as even for the purpose of this trial. Treatments were applied by lance at about 70-80 lb. pressure per sq. in. The wind was easterly for green cluster applications and no rain fell for several days afterwards ; the south-west wind at pink bud brought a heavy shower but not until some four hours after applications were completed. Slight drift from a N.N.E. wind affected a few trees at bud-burst, but no drifting occurred on any subsequent occasion.

Imprint records for all treatments were taken on 4th June, employing eight leaves for each treatment ; an analysis of variance was carried out on the data. The re-transformed means for eight leaves are given below ; figures which are bracketed do not differ significantly ($P = 0 \cdot 05$) :

Treatment	F	E	D	A	B	C	G	H
Mites per 8 leaves	0	1	1	2	2	12	56	245

It will be seen that all ester treatments were superior to no treatment by a considerable margin, but that the DNC-petroleum oil treatment (G) gave no significant control. Only DCPBS (C) was not significantly better than DNC-petroleum oil. CPBS at 0·2 per cent at green cluster (D) was as good as 0·05 per cent CPBS at green cluster plus pink bud (E) or at pink bud plus petal-fall (F). CPBS at 0·05 per cent at pink bud plus petal-fall (F) was significantly superior to CPBS (A), CPCBS (B), or DCPBS (C) at 0·1 per cent at green cluster.

There appears to be nothing to choose between these three esters for use at green cluster and there seems to be no advantage in using them at a concentration higher than 0·1 per cent, which gives a very low hatch indeed. The double applications of 0·05 per cent CPBS (E and F) gave excellent results. The green cluster plus pink bud applications might be expected to be less damaging ; this was borne out by an examination made on 26th June, when it was found that a small percentage of flower trusses had wilted, spur tissue being split, on trees receiving treatment F only. No damage was found on other trees except on those receiving treatment D, where an occasional withered leaf on fruiting spurs could be found. It is interesting to note that unsprayed trees were already bronzed by mite attack at this date.

Conclusions.

The laboratory estimates of the toxicity of certain chlorinated phenyl benzenesulphonates towards the winter egg have been verified in a small-scale field trial ; they indicate that pre-blossom applications should afford excellent control up to early June at least. The earlier the application, however, the higher is the concentration required for maximum effect likely to be ; alternatively, two applications in close succession may be successful.

Acknowledgements.

The CPBS was supplied by Ward, Blenkinsop & Co. while the CPCBS was obtained from the Dow Chemical Co.

Summary.

Field trials of new chemicals, based on laboratory studies, for the control of the winter egg of the Fruit Tree Red Spider Mite have been carried out on a small plot of trees of Worcester Pearmain. The results indicate that ‘ delayed dormant ’ applications of dinoseb as an amine salt are not likely to afford greater control than the standard DNC-petroleum washes. In attempts to improve the performance of dinoseb, the addition of an efficient wetting agent increased control, while a polyethylene polysulphide preparation offered somewhat greater promise as a sticker than did calcium caseinate.

Three chlorinated phenyl benzenesulphonates were found to give excellent control with one early (green cluster) application ; applied twice (green cluster plus pink bud *or* pink bud plus petal-fall) at a lower concentration, one ester gave excellent results, although some damage was caused by the post-blossom application.

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THE HATCHING OF SUMMER EGGS OF THE FRUIT TREE RED SPIDER MITE, *METATETRANYCHUS ULMI* (KOCH), UNDER ARTIFICIAL CONDITIONS

By A. H. M. KIRBY and R. G. GAMBRILL

The method used for bio-assay of chemicals using the summer eggs of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), has been described by Eaton and Davies (1950) ; a modified procedure was reported by Kirby and McKinlay (1951). In both cases, the treated leaf material was stored (under conditions providing adequate humidity) upon a laboratory bench receiving only northern light and no artificial heat. There were thus diurnal variations in both light and temperature akin to those experienced by eggs in the field, although the intensity of daylight was lower and the temperature variation in this laboratory was, generally speaking, considerably smaller. The time taken for hatching in this laboratory was usually 10-12 days (Eaton and Davies, 1950), but in 1951 hatching was delayed, even up to 22 days in some tests.

In 1952, a specially designed experiment was undertaken to assess the relative toxicities of a group of closely-related chemicals. To cut down variation between tests, treated material was stored at a steady temperature likely to promote hatching in a minimal time, an electric incubator at 24° C. being used. The experiment was a complete failure for an entirely unknown reason ; the percentage hatch of the undipped controls varied widely in a remarkable manner, as shown in Fig. 1. Leaves bearing adequate numbers of eggs had been brought in as usual from an unsprayed orchard ; owing to the unusually early season, eggs were sufficiently numerous by 12th June (second generation) and ten daily series of tests were completed by the 22nd. As will be seen from Fig. 1, only the undipped eggs of 16th June (test 222) hatched normally ; the percentage hatch in the remaining batches fell from the 12th (test 219) to the 19th (test 225), thereafter rising until the 22nd (test 229). No satisfactory explanation can be suggested for this result, but it led to a study of the effect of temperature, including diurnal variation, and to a less extent of light, upon the hatching of field-collected eggs, both in 1952 and 1953.

Methods.

1952 experiments.

Leaves of Worcester Pearmain apple with a high infestation were brought in on 8th, 15th, and 24th July, and 6th and 7th August ; eggs present at the first two dates were of the third generation, but on the remaining dates mixed generations were present third and fourth on 24th July, and fourth and fifth in August. The leaves were cleared of all stages other than eggs ; circles were punched out to provide 150 to 300 eggs per test and stored in closed petri dishes under one or another of six conditions (except on 8th July when only five conditions were employed). A new procedure introduced in 1952 tests was the use of a peripheral ring of moistened beer-filter, consisting of compressed paper pulp (Keyworth, 1951), in place of the filter-paper previously used to maintain humidity without condensation in the dish : this had the advantage that the leaf circles were not in contact with moisture and hence were less liable to be damaged by growth of moulds.

The six conditions employed were as follows :

1. 24° C. continuously, in the dark (incubator) ;
2. 18° C. continuously, in the dark (incubator) ;
3. 24° C. for 16 hours, in the dark (incubator) ;
   18° C. for 8 hours, in the dark (incubator) ;
4. 18° C. for 16 hours, in the dark (incubator) ;
   24° C. for 8 hours, in the dark (incubator) ;
5. Laboratory temperatures, in the dark (covered) ;
6. Laboratory temperatures, daylight from north window.

Condition 5 (not used on 8th July) was achieved by covering the dishes on the bench with a hurricane lamp glass which had been painted black and closing the top with a petri dish lid lined with black paper.

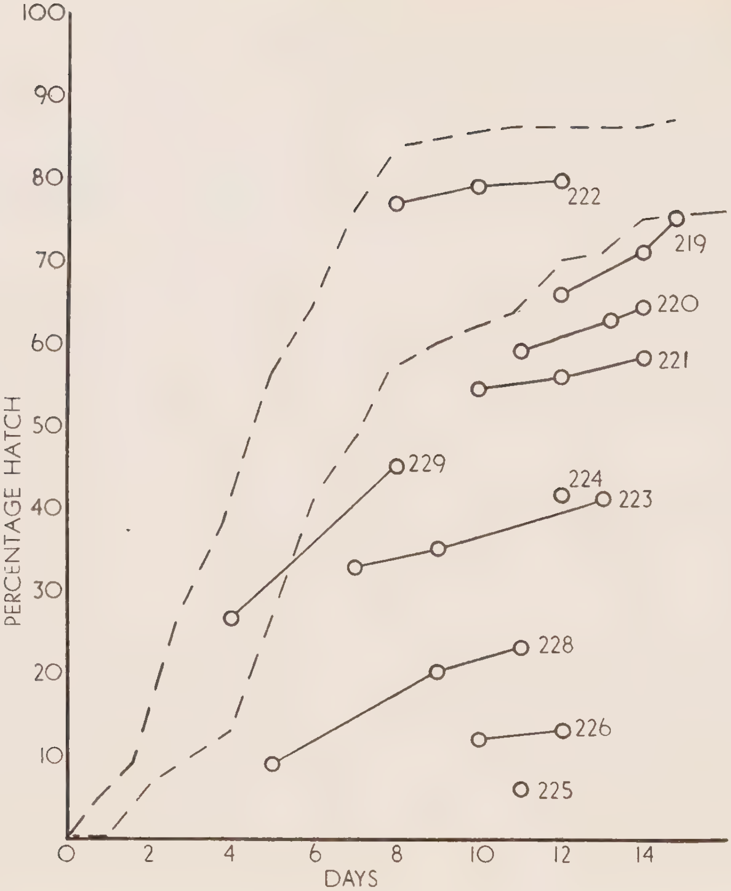

Fig. 1.

Percentage hatch of control (undipped) eggs brought indoors daily in 1952 from 12th June (test 219) to 22nd June (test 229), inclusive, and maintained at 24° C. continuously, in the dark. Dotted lines indicate upper and lower limits for five series of eggs treated in the same way between 8th July and 7th August, 1952.

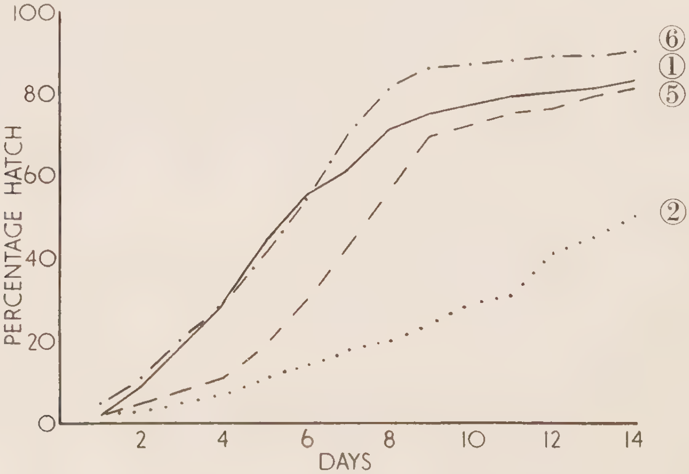

Fig. 2.

Average cumulative hatch of untreated eggs brought indoors on five occasions between 8th July and 7th August, 1952, and stored under conditions shown under Fig. 3.

1953 experiments.

Similar tests to those of 1952 were carried out with mixed third and fourth generation eggs brought in on 24th, 25th, and 27th July. The same technique was used, but only conditions 1, 2, 5, and 6 were employed. For condition 5, the lids consisted of tight-fitting bases of entomological collecting tins. The dishes in condition 6 were covered with unpainted lamp glasses, to obviate differences between 5 and 6 due to draughts.

Results.

Unhatched eggs were counted at one, two, or three day intervals, as convenient, and recorded as a percentage of the total eggs present on the first day of the test. The average percentage hatch was calculated for successive days after the commencement of the tests and plotted for each condition. Fig. 2 shows the average cumulative hatch for the 1952 series for conditions 1, 2, 5, and 6, and Fig. 3 the same for 1953.

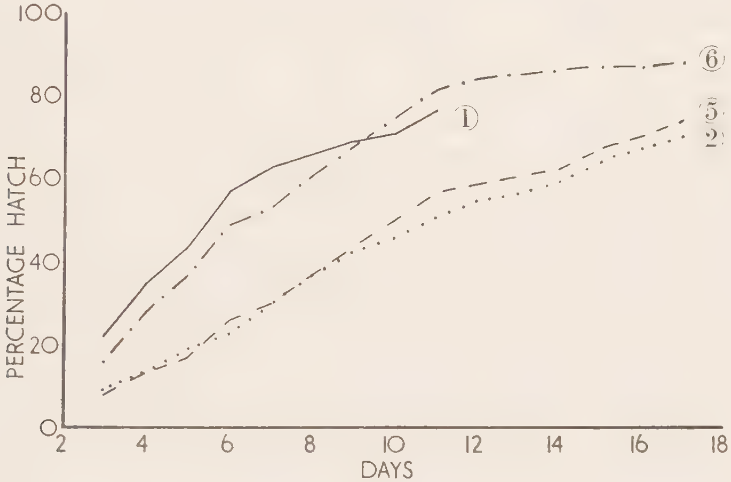

Fig. 3.

Average cumulative hatch of untreated eggs brought indoors on 24th, 25th, and 27th July, 1953, and stored under conditions shown below.

① At 24° C. continuously in dark.
② At 18° C. continuously in dark.
⑤ At laboratory temperatures in dark.
⑥ At laboratory temperatures in diffuse daylight.

It is at once apparent that satisfactory hatching was obtained under both condition 1, 24° C. continuously in the dark, and condition 6, laboratory bench, uncovered. On the other hand, storage at 18° C. in the dark, condition 2, slowed up development of the eggs profoundly, perhaps more so in 1952 than 1953. Under condition 5, where storage was similar to condition 6 save for exclusion of light, there is less agreement between the two years. In both years development is retarded for 4-5 days, but whereas in 1953 this retardation was maintained, in 1952 it was not. As a result, in 1953 hatching under condition 5 is not significantly different from that under condition 2, but in 1952, hatching under condition 5 follows the same trend as that under condition 6 but about two days later and to about 80 per cent maximum instead of 90 per cent. The explanation of this difference in reaction to the same conditions in two different years is not easy to discover, but it may be that condition 5 is intermediate between condition 2 and the rest in both years. That conditions 1 and 6 elicited very similar responses in both years is shown in Fig. 4, where the 1952 and 1953 lines for condition 1 are virtually identical, and those for condition 6 do not differ significantly. There is, therefore, no reason to suppose that eggs were more viable in one year than in the other.

In dealing with populations of eggs of mixed ages, one could expect that percentage hatch plotted against time would give a straight line; this is indeed the case for the less favourable conditions (2 in 1952, and 2 and 5 in 1953). The early part of the lines for conditions 1 and 6, up to about 8-10 days, can also be regarded as straight; these lines, however, flatten considerably after that period, although hatching is still going on at least up to the sixteenth day. It should be pointed out that in the case of condition 1, the constant temperature of 24° C. has an adverse effect on the leaf-circles which become more and more decrepit after about twelve days, making it difficult to take prolonged records.

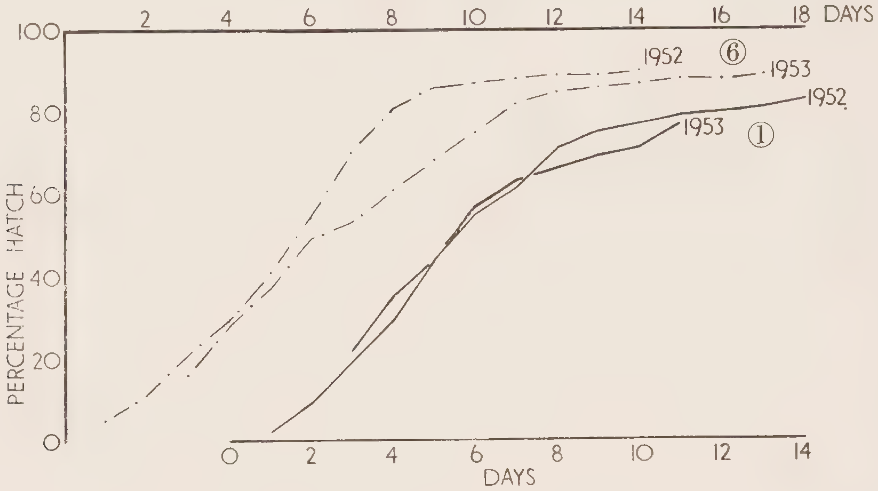

FIG. 4.

Average cumulative hatch of untreated eggs for 1952 and 1953 stored as follows:

① At 24° C. continuously in dark.

⑥ At laboratory temperatures in diffuse daylight.

Fig. 5 gives the average cumulative hatch under conditions 3 and 4 for 1952, together with the lines for conditions 1 and 2 for the same year. Apart from a slight lag, not exceeding 24 hours, the lines for the split conditions (3 and 4) are substantially the same as that for 24° C. continuously (1), especially from the ninth day onwards. In all three cases, a hatch of about 80-90 per cent has been reached by the fourteenth day, whereas at 18° C. continuously (condition 2) the hatch has then only reached 50 per cent. It is clear from these lines that light is not essential for hatch, or, if so, it cannot be more than

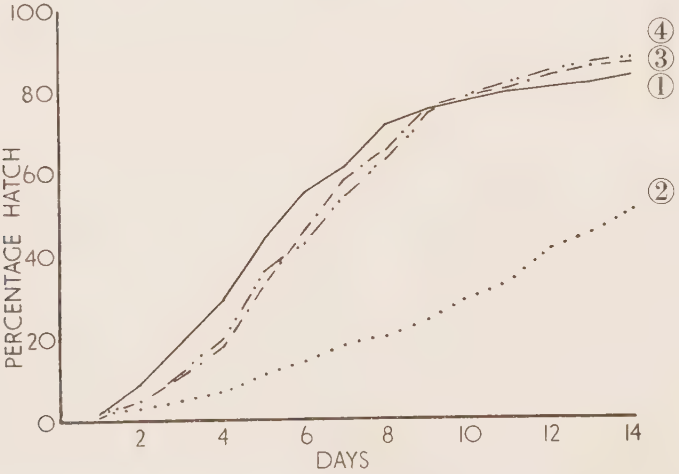

FIG. 5.

Average cumulative hatch of untreated eggs brought indoors on five occasions between 8th July and 7th August, 1952, and stored as follows:

① At 24° C. continuously in dark.

② At 18° C. continuously in dark.

③ At 24° C. for 16 hours alternating with 18° C. for 8 hours (in dark).

④ At 18° C. for 16 hours alternating with 24° C. for 8 hours (in dark).

that received during the fifteen minutes or so exposure per 24 hours or more during counting. On the other hand, temperature has a marked effect on the *rate* of hatching, as would be expected. However, the eggs need not be at the elevated temperature for more than eight hours out of the twenty-four ; it is interesting to speculate whether the period need be as long as this.

The difference between the hatching under condition 5 as compared with 6, especially in 1953, calls for further comment. It would appear that covering the eggs maintained at laboratory temperatures may reduce the hatch to that obtained at 18° C. in an incubator. The eggs under condition 5 were not in fact at 18° C. all the time ; they would often be at a lower temperature, but this would apply to eggs under condition 6. It seems possible that the absence of light may have had an influence on the rate of development. Such an effect, if it exists, must be eliminated where the temperature is maintained at 24° C. even for only one-third of each 24-hour period, perhaps provided the temperature does not fall below 18° C. in the rest of the period.

These results do not support the view that the erratic hatching of second generation eggs in 1952 was due to storage in an incubator at 24° C., and the series of results illustrated in Fig. 1 remains unexplained. The eggs used in the 1951 tests, although stored under condition 6 as for that year, seem to have behaved rather like those under condition 5 of 1953, and this may reflect the somewhat lower temperatures.

Summary.

Summer eggs of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), were maintained under various conditions in the laboratory and the rate and extent of hatching observed during 1952 and 1953.

It is evident that the summer eggs of *M. ulmi* can hatch in a normal manner under suitable artificial conditions.

Light is not essential, at least beyond the diffuse daylight reaching the eggs during the short period (approx. 15 minutes) required in every 24 to 72 hours for counting. It may increase the rate of hatch when temperatures vary not only diurnally but also from day to day as in the field. But it is usual to get as rapid and complete hatch of eggs maintained at 24° C. in an incubator as at laboratory temperatures and light intensity.

A temperature of 24° C. continuously gave a much greater rate of hatch than did one of 18° C., in the virtual absence of light.

The use of controlled temperature conditions, in the absence of light, did not give quicker or greater hatch than storing on the bench in an unheated laboratory with a northerly aspect.

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A RAPID METHOD OF MEASURING COPPER DEPOSITS ON LARGE NUMBERS OF INDIVIDUAL LEAVES

By M. ALLEN and F. W. M. LLEWELYN*

In the course of an investigation into the factors involved in the damage caused to trees by chemicals applied as sprays, it became necessary to determine the quantity of liquid retained by the leaves after spraying, and to relate this to the amount of damage induced in the leaf. A chemical which could be relied upon to cause damage, and which could be easily estimated, was required, and initially ammonium thiocyanate was used. This material damages the leaf by scorch, causing the affected portions to dry out, and the amount of damage can be readily measured (Llewelyn and Allen, 1952). However, the method used for determining the volume of spray liquor retained by the leaf, which involved washing the leaves in a solution of ferric alum and measuring the intensity of colour in the resulting solution, was unsatisfactory ; it was not possible to recover all of the ammonium thiocyanate applied to the leaf, probably because some of it had entered the leaf, or been adsorbed at the leaf surface. To obviate this difficulty it was decided to employ an ashing technique to recover the toxicant from the leaf, and a new toxicant stable to such treatment was sought ; copper sulphate, which also causes damage by scorch, was selected. It was now necessary to devise a method of estimating the amount of copper in large numbers of single-leaf samples quickly and accurately. In the first place, a colorimetric method using sodium diethyldithiocarbamate as the colour-developing reagent was used, but this was abandoned in favour of a method, described below, based on that described by Wetlesen and Gran (1952), using bis*cyclo*hexanone oxalyldihydrazone as the colour-developing reagent. It is superior in that it is more convenient, rapid, and pleasant in use. Williams and Morgan (1954) have used this compound for the estimation, in relatively large samples, of copper occuring naturally in plant tissues.

Method.

Apparatus.

Metal trays.—Make a metal tray by bending a strip of 20-gauge mild steel sheet, 27 cm. by 8½ cm., at right angles at both ends so that the length of the upright portions is 6½ cm. and of the base 14 cm. ; weld a piece of sheet, 14 cm. by 6½ cm., onto one end to form a back to the tray ; in the back drill ten ½-inch diameter holes, to reduce its resistance to air-flow. Six such trays are needed.

Furnace.—A muffle furnace, internal dimensions 8 cm. high by 16 cm. wide by 34 cm. deep, and so wound that one end was much hotter than the other, was used for this work. The hotter end was raised so that the furnace was inclined at an angle of five degrees to the horizontal, and a centrifugal fan was mounted on the door at this end so that a gentle stream of air could be passed through the furnace ; a movable baffle was placed just inside this door. The trays were introduced into the furnace at the colder end, where the door is permanently open, and removed at the hotter end after raising the door and removing the baffle. The highest temperature in the furnace was adjusted, by means of a Simmerstat energy controller, to a dull red heat just below the softening-point of glass specimen tubes to be held in the trays.

Reagents.

Biscyclohexanone oxalyldihydrazone.—Dissolve by warming 0·5 g. of bis*cyclo*hexanone oxalyldihydrazone in 100 ml. of a mixture of equal parts of water and ethanol, and filter ; cool the filtrate and add it to a solution of 13 g. of citric acid and 21 ml. of ammonia solution (S.G. 0·880) in water ; make up to 2 l. with distilled water and store in a brown glass bottle. The solution can be kept for several days without signs of deterioration.

Sulphuric acid.—A 0·1 N solution.

Procedure.

Dry the leaves in an oven at 50° C. overnight ; allow them to cool and then weigh them individually, in order to obtain an estimate of the size of the leaf. Place each leaf in a 3-inch by 1-inch glass specimen tube, then stack the tubes three deep, in batches of fifteen, in the metal trays, so that the tubes lie on their sides with their open ends at the front of the trays. Introduce the trays into the furnace so that the open ends of the tubes are foremost ; the operating part of the furnace holds three trays of tubes, and these trays are moved on every ten minutes, so that fifteen tubes emerge every ten minutes, and each leaf is in the furnace for thirty minutes.

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On removal from the furnace, allow the tubes to cool to room temperature, then add 10 ml. of 0·1 N sulphuric acid to each tube and leave to stand for thirty minutes. While they are standing, take an adequate number of 5-inch by ½-inch test tubes, and into each place 8 ml. of the bis*cyclo*hexanone oxalyldihydrazone reagent ; take aliquots from the solutions in the specimen tubes after shaking, and add them to the solutions in the test tubes. The aliquot should contain not more than 160 μg of copper sulphate, and should not exceed 1·5 ml. of 0·1 N acid. Shake each test tube, and allow it to stand for one hour for the colour to develop, then measure the depth of colour using an Hilger H810 Biochem Absorptiometer with a Kodak 55 filter (maximum absorption at 545 mμ). Compare the depths of colour obtained with those obtained from known amounts of copper sulphate ; over the recommended concentration range there is a linear relation between the logarithm of the intensity of colour and the concentration of the copper sulphate present.

Results.

To determine the accuracy of the method, known amounts of a solution containing 2·500 g. of copper sulphate ($CuSO_4.5H_2O$) per 100 ml. were pipetted onto individual apple leaves using a micrometer syringe, the solution allowed to dry, and the amount of copper present in the leaves determined as described above. The results obtained are given in Table I.

TABLE I.

ESTIMATION OF KNOWN AMOUNTS OF COPPER SULPHATE APPLIED TO LEAVES.

Quantity of copper sulphate applied in mg. per leaf.	Quantity of copper sulphate found in mg. per leaf. (Mean of 5 determinations.)	Standard deviation in mg. of a single determination. (From 25 determinations.)
0	0·05	*
0·5	0·56	0·02
1·0	1·05	0·04
1·5	1·53	0·06
2·0	2·08	0·08
2·5	2·56	0·10

This method has been in use for the past season, and it has been found possible for two persons comfortably to carry out over 200 determinations in a normal working day.

Summary.

A method is described for the estimation of copper deposits on leaves, using bis*cyclo*hexanone oxalyldihydrazone as colour-developing reagent. The method is rapid ; over 200 determinations a day can be made with ease.

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* The standard deviation of this determination was based on five measurements, and was 0·015 mg.

THE ESTIMATION OF LIME-SULPHUR DEPOSITED ON LEAVES

By M. ALLEN and F. W. M. LLEWELYN*

The use of lime-sulphur as a fungicide has been standard practice in horticulture for many years, and a great deal of information is available on the relative merits of spraying various concentrations of the substance on to trees to control scab, mildew, and insect pests. There are, however, no data on the amounts of lime-sulphur deposited on the leaf—the only quantities mentioned are the concentration and the number of gallons per acre of orchard, or, if unusually precise, the number of gallons used per tree. This is due to the difficulty of measuring small quantities of lime-sulphur.

Lime-sulphur is an unstable compound which can be readily decomposed by oxidizing or reducing agents to a wide variety of sulphur compounds, and much work has been done on this topic. Some of these compounds are gaseous and are lost to the atmosphere when lime-sulphur is applied to leaves, rendering it difficult to use the sulphur content as a measure of the quantity of lime-sulphur present. The micro-estimation of the calcium content has until now presented difficulties in that it involved precipitating the calcium as oxalate, and either weighing, or filtering and estimating the oxalic acid colorimetrically. The advent of chelating agents, however, has made it possible to determine micro-quantities of calcium accurately, cheaply, and quickly, so that one can carry out enough analyses to be able to study sufficient samples in a statistically designed field experiment. The object of this note is to describe the method of estimation used at this Station to compare methods of spraying lime-sulphur in an orchard. The field trial itself will be described in a later paper.

The method is an adaptation of a means of measuring the hardness of water, described by Houlihan (1952), and consists, in essence, of picking the sprayed leaf, washing it in a buffer solution, and estimating the calcium which has passed into the solution.

Reagents.

Buffer solution.—2·5 g. of caustic soda and 1·25 g. of sodium sulphide nonahydrate are dissolved in 25 ml. of water, and this solution mixed with a solution of 10 g. of borax in 200 ml. of water. The resulting solution is made up to 250 ml. with water, and kept as a stock solution ; 20 ml. of this solution are diluted to 1 litre for use.

Indicator.—1 g. of Eriochrome black T is mixed with 30 ml. of 0·033N sodium carbonate and made up to 100 ml. with 99 per cent *iso*propanol.

Chelating solution.—4 g. of the disodium salt of ethylenediamine tetra-acetic acid ; 0·86 g. of caustic soda ; 1·33 g. of magnesium sulphate heptahydrate ; 1 ml. of a 20 per cent solution of dioctyl sodium sulphosuccinate (Aerosol OT) in ethanol. These are all dissolved in distilled water and the volume made up to 1 litre.

Method.

As soon after spraying as possible, the leaves are picked and immersed in 10 ml. of buffer solution contained in a 3 in. × 1 in. glass specimen tube, each leaf having its own tube. After 10 minutes the leaf is removed, dried in an oven at 50° C. overnight, and its dry weight taken as a measure of the leaf size. 5 ml. aliquots from the leaf washings are transferred to fresh 3 in. × 1 in. tubes, and to each tube is added three drops of indicator. The resulting solution is titrated with the chelating solution from a burette reading to 0·02 ml. The burette is fitted with a fine jet, and this, together with the presence of the Aerosol OT (a wetting agent), enables one to carry out the titration using very small drops. Adequate stirring is obtained by bubbling a gentle stream of air through the contents of the specimen tube. The end point of the titration is reached when the addition of one drop changes the colour from violet to bluish green. Good warning of the approach to the end point is given, but the final drops should be added slowly because this colour change takes about five seconds to develop ; the sharpness of this change is enhanced by the presence of the magnesium sulphate. The chelating solution is standardized by titration against buffer solutions containing known quantities of the lime-sulphur used in the spraying.

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Discussion.

The accuracy of the chemical estimation was determined by diluting lime-sulphur with the buffer solution until the equivalent of 0·0005, 0·0010, 0·0015, and 0·0020 ml. of 100 per cent lime-sulphur were present in 10 ml. lots of buffer solution. The chelating solution was titrated against four samples of each of these strengths, and a straight line relating the volume of the chelating solution to the quantity of lime-sulphur was obtained. This line has the equation

$$Y = 0\cdot016 + 476x,$$

where Y is the estimate of the volume of chelating solution in ml. needed for x, the quantity of 100 per cent lime-sulphur in ml. The points are distributed about the line with a standard error of $5\cdot2 \times 10^{-5}$ ml. of 100 per cent lime-sulphur.

When measured quantities of 1 per cent lime-sulphur were pipetted on to leaves, using a micrometer syringe, and the amount of lime-sulphur recovered by the buffer solution determined, it was found that the line relating volume of lime-sulphur applied to the volume of chelating solution titrated, could be expressed by the equation

$$Y = 0\cdot098 + 334x.$$

where Y is the estimate of the volume of chelating solution in ml. needed for x, the quantity of 100 per cent lime-sulphur in ml. The points are distributed about the line with a standard error of $1\cdot0 \times 10^{-4}$ ml. of 100 per cent lime-sulphur.

The difference in the intercepts of the two lines, 0·082, shows that the equivalent of 0·000176 ml. of 100 per cent lime-sulphur is extracted from Cox's Orange Pippin apple leaves by the buffer even when no lime-sulphur is applied. The ratio of the slopes, 334/476, shows that only 72 per cent of the lime-sulphur applied is recovered in the buffer solution.

To determine whether or not more efficient washing techniques could be found, the same quantities of lime-sulphur as used in the recovery trial above were this time pipetted into 10 ml. of buffer solution into which the apple leaf was already immersed. The lime-sulphur thus had no chance of drying on the leaf, and would have to pass from the solution to the leaf instead of from the leaf to the solution. After 10 minutes, aliquots were titrated with the chelating solution. From the results of these titrations a line was derived having the equation

$$Y = 0\cdot101 + 408x,$$

The points are distributed about the line with a standard error of $7\cdot7 \times 10^{-5}$ ml. of 100 per cent lime-sulphur. The slope of this line indicates that some 14 per cent of the lime-sulphur was not recoverable from the solution, presumably because of adsorption. Thus, however good the washing technique, one cannot hope to achieve better than 86 per cent recovery with this buffer solution. This solution was selected to provide optimum conditions for the titration, and it was considered inadvisable to change it ; under these circumstances, it is thought that the washing technique described, which gave 72 per cent recovery, is adequate.

This method was designed to measure the results of experiments carried out in an orchard, in which the deposit on the leaves varies widely ; under such conditions, small differences between treatments can only be rendered significant by taking large numbers of replicates. The technique described does allow for large numbers of replicates to be conveniently handled, and the standard error of a single determination is small compared with the differences to be expected within a treatment. The results obtained are comparative within an experiment, but if, in planning an experiment, provision is made for the application of known amounts of lime-sulphur to samples of the leaves, the efficiency of recovery can be determined, and the results expressed on an absolute scale.

Summary.

A rapid method of estimating the amount of lime-sulphur retained by leaves sprayed in the orchard is described. The method is based on the determination of the calcium content of the lime-sulphur by titration with the disodium salt of ethylenediamine tetra-acetic acid.

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Part IV

BULLETINS FOR FRUITGROWERS

SOME FACTORS AFFECTING THE SCOPE FOR THE USE OF HERBICIDES IN FRUIT CULTURE*

By F. R. TUBBS

The preceding papers have illustrated the extent to which the scope for the use of herbicides in agriculture and in vegetable culture is influenced, and in some cases clearly limited, by the characteristics of a crop and by its cultural requirements. Even more striking examples may be found in fruit culture ; we have not so far had occasion to consider the type of problems arising where the free growth of weeds for several months of the year forms part of an accepted cultural system, or where intergrown grass swards are used to increase the quality and quantity of marketable produce. This diversity of practice requires a brief survey of some of the more important economic and cultural aspects of weed control in fruit plantations as a very necessary introduction to those specialized problems which will, I hope, receive more detailed discussion in the later proceedings of this Conference.

The acreages, in England and Wales, of the more important kinds of fruit are set out in Table I. The great predominance of tree fruit acreage over soft fruit acreage is in contrast to the position in Scotland where the tree fruit acreage is negligible but where the culture of bush fruit and strawberries occupies nearly 10,000 acres.

TABLE I.

AREAS UNDER FRUIT, IN THOUSANDS OF ACRES.

(From ' Agricultural Returns, England and Wales, 1951 '.)

Tree fruit over crops, fallow, or grass	263
Tree fruit over bush fruits or strawberries	13
Bush fruit and strawberries not under tree fruit	35

The relative importance of the different kinds of tree fruits can be gauged from Table II ; this also provides an indication of the proportion of young plantations and of the relative importance of arable and sward cultures in England and Wales. The acreages in Scotland are shown in brackets.

TABLE II.

AREAS UNDER TREE FRUIT, IN THOUSANDS OF ACRES.

(From ' Orchard Fruit Census, England and Wales, 1951 '.)

	Under 7 years.	7 years and over.	Total.	Possible acreages over arable.†	Possible acreages over grass.†
Apples	25	103	**128** (0·3)	63	65
Cider and Perry Fruit	3	43	**46**	5	41
Plums	7	36	**43** (0·5)	37	6
Cherries	4	14	**18**	2	16
Pears	5	11	**16**	13	3

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* Paper read at First National Weed Control Conference, 3rd November, 1953 (Morning Session), reprinted with permission.

† These figures are ' inspired guesses ', having no statistical basis.

TABLE III.

AREAS UNDER SOFT FRUIT, IN THOUSANDS OF ACRES.
(From 'Agricultural Returns, England and Wales, 1951'.)

	Total.	Possible acreages under tree fruits.*	Possible acreages in open.*
Strawberries	17·5 (1·5)	3·5	14·0
Raspberries	4·3 (7·0)	1·3	3·0
Currants	17·5 (0·5)	3·9	13·6
Gooseberries	7·0 (0·25)	4·0	3·0
Other berries	1·2 (0·6)	0·4	0·8

In Table III are set out the acreages under bush fruits and strawberries, together with estimates of the proportion cultivated under tree fruits. To these should be added the areas of soft fruit cultivation in Scotland, shown in brackets.

It is unfortunate that the Fruit Census provides no basis for estimating the acreages of tree fruit being grown under the main cultural systems referred to below, but we know that systems vary markedly with the district, with the kind of fruit, and according to whether the trees are young or well established. The position as regards bush fruit and strawberries is simpler, in so far as clean cultivation is the rule, but even here we find that of 47,500 acres in England and Wales, 12,500 acres or more are grown under tree fruits.

The tree fruits may stand over fallow, over autumn weeds or cover-crops grown to provide organic matter and to reduce winter leaching, over grass swards closely gang-mown or grazed during the spring and summer months, over vegetable crops, occasionally over farm crops when freshly planted, or over bush fruits or strawberries. It is clear, therefore, that, over a large proportion of the acreage under fruit, not the fruit alone but a combination of crop and underculture must be considered.

With this brief reference to the acreage position and to the wide variety of cultural practices employed, I will turn to the question of the cost of weed control in fruit culture. I am greatly indebted to Mr. Folley and Mr. Rowe, of Wye College, for an analysis of weed control operations on four Kentish farms over a period of three years. I believe the figures can be regarded as illustrative of the position on farms on which the standard of culture, and of weed control, is above the average for the country as a whole.

TABLE IV.

THE COST OF WEED CONTROL.

Fruit.	Number of crops considered.	Labour on weed control as a percentage of total labour on crop.	Cost of weed control operations as a percentage of cost of production of crop.
Tree fruit over grass.			
Apples	8	1·6 to 6·4†	0·8 to 3·8†
Tree fruit over arable and autumn weeds.			
Apples	6	4·0 to 4·8	3·9 to 5·6
Pears	3	6·6	5·1
Plums	3	10·2	9·6
Small fruit.			
Currants	5	3·2 to 17·9	7·3 to 8·1
Raspberries	4	3·6 to 39·9	14·3 to 26·8
Strawberries	9	11·3 to 31·2	6·5 to 23·2

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* These figures are 'inspired guesses', having no statistical basis.

† An exceptional value, representing an unusual emphasis on 'trimness'.

They found that all but negligible weed control operations occurred from March to July inclusive. Two measures of their economic importance were built up ; for this purpose cultivation of arable areas was included as a weed control measure but the cost of gang-mowing grass swards was omitted :

Firstly, the proportion of the total man-hours of labour spent on controlling weeds, whether by hand or machine (see Table IV).

Secondly, the proportion of the total cost of production, excluding depreciation, accounted for by man and machine work on weed control (see Table IV).

Folley and Rowe found the following trends—weed control is a heavier burden in young orchards than in old, with dessert than with culinary apples, in arable orchards than in grass, in young strawberry and raspberry plantations than in old, and so on. All these contribute to the ranges given in Table IV ; we have also to remember that, as the possible advantages of summer cultivation additional to the elimination of weed competition have been ignored, the figures may somewhat over-emphasize the real cost of weed control.

The available data indicate that weed control is not to be regarded as a serious economic factor in fruit culture save in the case of strawberries and bush fruits where, in some cases, there may be substantial scope for savings in labour and in production costs. The relatively high figure for plums is of interest ; it is probably related to the simplicity of culture and the lower cost of pruning. Even so, far more may be spent on pest and disease control in plums than on weeds.

Two further questions must, however, be faced. Firstly, how stable are the present systems of fruit culture ? Whatever economic stresses arise during the next decade, I feel that the requirement for fruit of high market and storage quality will preclude any tendency to revert to undercropping ; rather can we anticipate a reduction in both arable and undercropped acreages as the extensive post-war plantings become established and as the management of orchard swards is refined.

The second question is whether an element of systematic but unrecognized loss due to uncontrolled weed growth occurs in our fruit culture. There is no evidence that this is the case : although serious harm can be caused by unrestricted weed competition, especially to young trees during the early years of establishment, the effects of a properly managed grass sward or of autumn weeds in tree fruit orchards are, on balance, advantageous. Especially is this the case when the requirement for long-term maintenance of soil structure and soil fertility is taken into account.

The foregoing survey of the general position must not be allowed to obscure, however, the distinct, but clearly limited, scope for the use of herbicides in tree fruit orchards for specific ends. Time does not permit of detailed discussion, but attention may be drawn to the desirability of means for :

(*a*) reducing the number of summer cultivations ;

(*b*) controlling thistle, bindweed, couch, dock, ground elder, or nettle, in arable areas or over mulches, and controlling docks, etc., in orchard swards of which clover is a valued component ;

(*c*) influencing the botanical composition firstly of autumn weed growth to check excessive growth of, for example, either annual nettle or fat-hen, and secondly, of the early phases of tumble-down swards ;

(*d*) checking the growth of perennial weeds and grass around the trunks, especially in young orchards ;

(*e*) lastly, and most ambitious, limiting the growth of swards in spring and summer, and therefore the number of gang-mowings required to maintain a satisfactory balance between tree and sward.

In all these cases there is the obvious need to attain a high degree of selective action, whether by extreme refinement in the technique of application, or by virtue of the specific properties of the herbicide. We must bear in mind that the effects of herbicidal treatment at the time of fruit bud differentiation frequently do not become apparent until the succeeding year, and also that the risk of damage from a given contamination by a herbicide varies markedly both according to the variety and the season of application.

Here I must sound a warning as to the possible danger of too limited an approach to the problems of weed control in fruitgrowing areas. Our fruit crops are, to very great degree, dependent upon cross fertilization ; in other words, the industry relies for its livelihood on the activity of a wide variety of pollinating agents, such as blossom beetles, wild bees, and the hive bee. Their efficiency is markedly reduced by adverse weather conditions ; particularly is this the case with the hive bee. Thus, in some years we may be much more dependent for our crop on the activity of wild species than we yet realize. Changes in the pattern of farm cropping (for instance, the great reduction in the acreages under field beans or catch crops of mustard), together with the great and desirable reduction in the weed population in cereal crops resulting from the use of herbicides, must inevitably affect the population level of these insects and therefore their frequency in the orchard in early spring.

Already in many parts of Kent there is what amounts to a serious ' starvation period ' following the fruit blossom period. We have as yet no means of knowing what the effects on crop would be were weed control in cereal crops to be indiscriminately extended over roadsides, hedges, field verges and other areas where weeds do not directly compete with valuable produce. All those interested in fruit culture would like to be assured that a careful watch is being kept upon the long-term effects, as well as upon the immediate advantages, that may result from the ever-widening use of selective weed killers.

The possibility of using, with due care, sodium chlorate and MCPA for the control of weed growth under apples is under investigation at East Malling, while Clift and Woodford have been associated in trials of chlorates, fortified oils, TCA, CMU, and 2,4,5-T for the control of weeds around the base of the trees. In America couch control has been achieved with TCA, with ammonium sulphamate, sodium chlorate, and with oils. It has also been reported in America that dinitro-fortified oil, supplemented by the use of carefully applied fuel oil sprays to control grass species, gave weed control under the special conditions of nursery tree rows as thorough as that achieved by hand hoeing.

In nurseries, under bush fruit, and among strawberries, no treatment is adequate that does not provide control of couch and of annual grasses, but means for the control of perennial weeds, especially bindweed and thistle, would be welcome in the meantime, whether by clearance of the ground before planting or by subsequent control.

Holly and Roach are studying the use of MCPA and 2,4-D in the control of bindweed under black currants, while Wakil (unpublished) suggested that weeds in raspberry beds might be reduced by the careful use of MCPA, and that a place might be found for autumn, rather than spring, use of TCA.*

In strawberries, the position is complicated by the fact that differential application is out of the question and a truly selective weed killer is required. Wakil found that DNBP (dinoseb) gave a useful degree of weed control in established strawberries, although harmful to maidens ; an April application was estimated to have saved two hoeings, but here again varying varietal susceptibility was found.

In both strawberry and bush fruit cultivation, there is obvious scope for the development of germination inhibitors, especially if effective on grasses. In a similar class to 2,4-D and MCPA we now have SES (sodium 2,4-dichlorophenoxy-ethyl sulphate) which has given variable but promising results (Roach and Tucker, unpublished).

We have no reason to expect the early discovery of ideally selective herbicides for use under bush fruits and strawberries. It is clear that, in the meantime, the real scope for advance is through improvements in the techniques and seasons of application of compounds already under test for other purposes. This Conference provides the ideal opportunity for discussing and pooling the experience which must provide the basis for such improvements.

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* See also page 118.

THE EXPERIMENTAL PLANTATIONS AT EAST MALLING

By J. H. WALKER

It is now five years since a brief description of all the experimental plantations was published. The last five years have seen considerable changes ; some of the older plantations have been grubbed and there have been extensive new plantings on the Bradbourne Park Farm land and elsewhere. A fresh plan and catalogue has therefore become necessary, as a guide to the plots and the scope of the experiments in progress. Changes are, of course, constantly being made as the research programme advances and widens.

Great East Plantation.

This is the original twenty-three acres bought by the Kent County Council for the Wye College Experiment Station when it was founded in 1913.

G1. This is now occupied by glasshouses, including an air-conditioned virus house, insectaries, potting shed, and frames.

G2. This consists of small temporary plantings for Plant Pathology and Entomology, including a block of Climax strawberries for studying the incidence of transient yellows in various clones.

G3. This, the earliest planting still extant on the station, is part of the pruning trial planted in 1915. Early Victoria (Emneth Early) apple trees, on seedling (French crab) rootstocks, selected for uniformity at planting, now show the variation in tree size and other characteristics due to the variability of the seedling rootstocks. Such trees are quite unsuitable as experimental material and equally undesirable for commercial planting.

G4. Most of this plot is a plantation of M.VII rootstocks to be grown into ‘ staddles ’ for framework grafting with new seedling apple varieties undergoing selection. Planted 1951-52.

G5. This consists of collections of material for breeding purposes, including collections of late flowering apple varieties grown as cordons, of *Ribes* species of possible value for crossing black currants, and of ‘ thornless ’ gooseberry hybrids.

G6. This consists of cordon apples of new dwarfiing rootstocks of the ‘M.IX Cross’ family, and new East Malling apple varieties. (Includes the original G7.)

G8. This was originally a large collection of apple and pear varieties grown as cordons, now mostly grubbed following the development of the National Fruit Trials. The plot is now planted with Mosaic-susceptible hops for virus experiments. There is also an experiment to test the suitability of different rootstocks growing as ‘ staddles ’ for future frameworking of new apple varieties (cf. G4).

G9. This consists of breeding material, peach varieties, *Pyrus pashia* and *Chaenomales* species.

G10. This is the first of the original apple rootstock trials planted 1918-19 with Lane’s Prince Albert on M.I-M.XI and M.XIII-M.XVI ; it is now used for Entomological trials, including the dispersal of Fruit Tree Red Spider Mite and the testing of spring and summer sprays against aphids.

G11. This is one of the original apple rootstock trials planted 1919-20 with Lane’s Prince Albert, an excellent indicator of rootstock potentiality, on M.I-M.XVI, Crab A, C, E, F, H, and 51. The trees on this plot have been very fully recorded, and in addition to the simpler records such as girth and crop taken on all trees, extension growths are still measured on some 50 of the trees. The half standards are Grenadier pollinators, planted 1923 ; some of these have recently been frameworked with Howgate Wonder. The trees of Grenadier on Northern Spy, a rootstock widely used in warmer countries because of its immunity to Woolly Aphid, demonstrate the poor growth common on this stock and emphasize the need for Woolly Aphid resistant stocks of better pomological performance now met by the recently introduced Malling-Merton series (see C9 and C10) ; these trees appear as tree 14 in several rows at the northern end of the plot. In row 7 are Lane’s Prince Albert on M.IX showing the extremely dwarf trees produced by this weak scion variety on this rootstock ; in adjacent rows are trees on the semi-dwarfing M.VII and on the very vigorous M.XII.

G12. This is one of the original apple rootstock trials planted 1919-20 with Worcester Pearmain, a scion variety of vigour about average for English dessert apple varieties, on M.I-M.XVI, Crab E, F, and 51. Trees on the very dwarfing M.IX and the very vigorous M.XVI, showing the contrast in size, can be seen on the eastern headland. Other trees of interest are those on the semi-dwarfing M.VII, e.g. row 5 tree 6; on M.IV, e.g. row 3 tree 6; and on the vigorous M.I and M.II on the northern headland. Originally a plantation of Worcester Pearmain and Bramley's Seedling, the trees of Bramley's were grubbed in 1934-35 and trees of Worcester transplanted from G13 into the resulting holes. James Grieve trees on unknown 'Paradise' rootstocks were transplanted from neighbouring plots as pollinators. Most of the transplanted Worcester were removed in 1950. The ten rows at the southern end were unpruned in early years, afterwards the branches were thinned out; the northern part has always been spur pruned. A grass sward was sown in 1930; the northern half was disced in 1941 and kept in arable cultivation till 1953 when the present sward was sown.

G13. This is one of the original apple rootstock trials planted 1919-20 at 15 ft. square with Bramley's Seedling as a very vigorous scion variety and Worcester Pearmain pollinators. The Worcester trees were removed in 1934-35 and the Bramley's thinned in 1939-40 to leave trees on M.I-M.XVI, and on Crab F and 51 at 30 ft. with the exception of a few trees that had been left in the thinning and frameworked with Grenadier in 1939 for pollination. Grass swards were sown at the same time as G12. Many trees are now scion rooted and for this reason there are no trees on M.IX; the smallest trees are those on M.VII, such as row 8 tree 6. Trees on M.II, such as row 12 tree 6, are very large indeed; the largest trees are on M.XII, e.g. row 6 tree 2, and have on occasion yielded over twenty bushels of fruit.

G14. This is one of the original apple rootstock trials planted 1919-20 with Bramley's Seedling on M.I-M.VII and M.X. No manure, apart from green crops, was applied before 1931, since when the plot has been used as a manurial trial for nitrogen and potash. Many of the trees are of interest as having received no nitrogen during the whole period, e.g. rows 2 and 4, 16, 18, and 20.

G15. These apple trees on M.IX, varieties Worcester Pearmain, Allington Pippin, Newton Wonder, and Cox's Orange Pippin (frameworked on Edward VII), were planted in 1929 and used for small-scale spraying trials against scab. They are now infected with two strains of Apple Mosaic, the severe Bramley Mosaic and the mild Lord Lambourne Mosaic, to study their effect on yield.

G16. This is now arable.

G17. This contains the meteorological plot with the following instruments: a Stephenson screen containing maximum, minimum, and wet and dry bulb thermometers, and a thermograph; a minimum thermometer on the grass; soil thermometers at 8, 24, and 48 inches deep; an unscreened minimum thermometer at 4 feet; a sunshine pillar with a Campbell-Stokes sunshine recorder; a 5-inch rain guage; Rogers soil moisture tensiometers at 8 and 28 inches; and a soil thermograph. The rest of the plot is occupied by plants for general virus investigations, including the graft transmissibility of Chat Fruit, Rubbery Wood of apples, Stony Pit of pears, and their effect on several varieties.

G18. This large collection of cordon trees was planted 1949-50 for the preliminary selection of new apple and pear seedlings raised here. The apples are worked on M.IX to bring the trees into cropping as early as possible, so shortening the time necessary for making the preliminary selection. The pears are on Quince A. There is also a collection of raspberry varieties of potential value for breeding purposes. The dwarf bushes are Worcester Pearmain apples on M.IX for trials of pre-blossom application of ovicides against red spider.

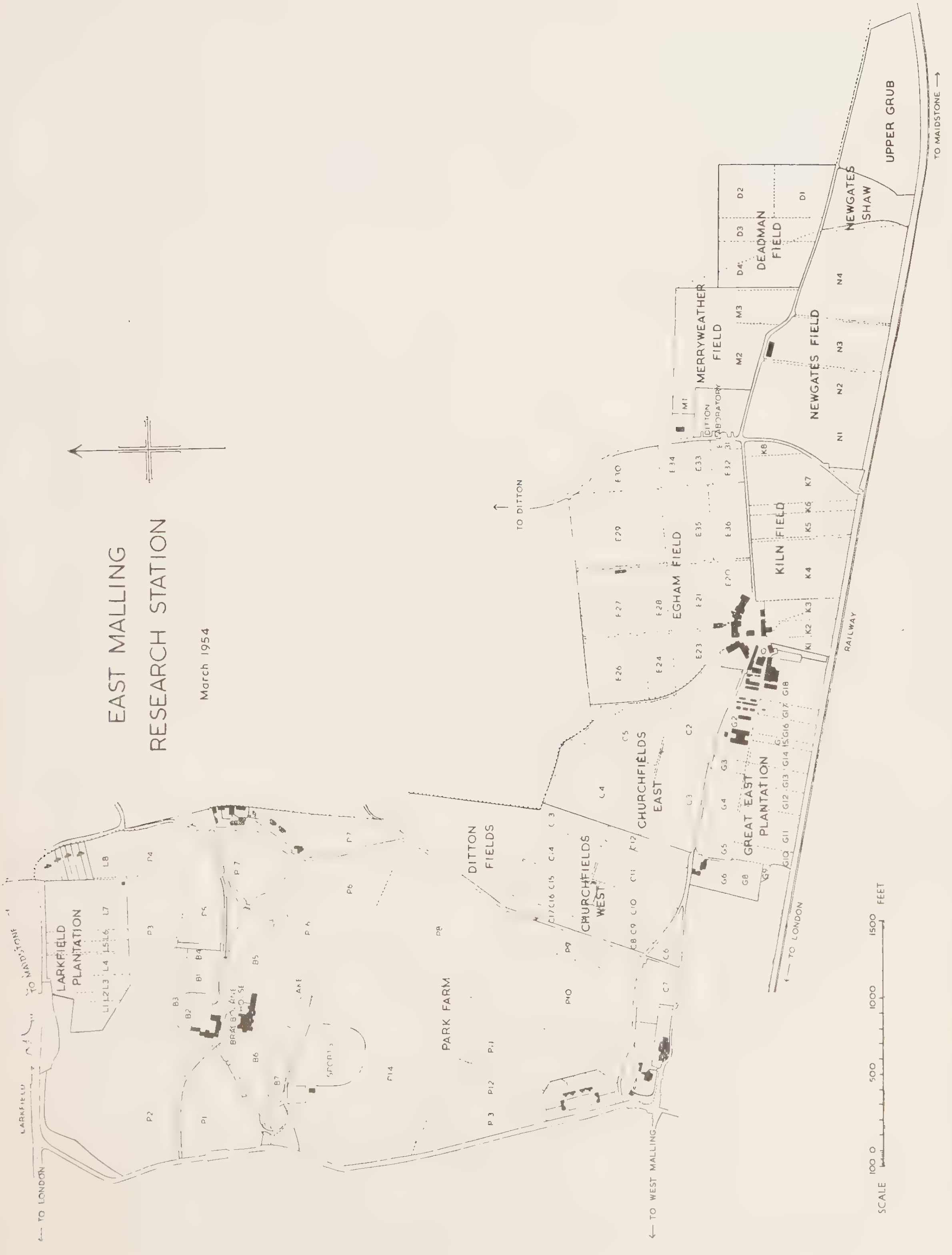
Egham Field.

This 40-acre field was acquired in 1919 with money raised by Mr. Percy Manwaring and the Kent National Farmers' Union, the Ministry of Agriculture also subscribing on a pound for pound basis.

E20. This is mostly arable at present. At the eastern end are several small blocks of apples for studying the factors involved in fruit bud differentiation and the relationships between number of flowering spurs and extension growth, using Cox's Orange Pippin, Miller's Seedling, Worcester Pearmain and Laxton's Superb on M.IX and M.XVI.

E21. This consists mainly of several blocks of trees for small-scale spraying trials and the testing of new fungicides.

The dwarf pyramid apples on M.VII were planted 1949-50 and grassed down autumn 1950. The dessert varieties are Cox's Orange Pippin, James Grieve, and the culinary varieties Bramley's Seedling and Newton Wonder; the guard trees are Edward VII. Dwarf pyramids are useful for this purpose because the individual trees can be easily screened from spray drift with hessian screens. The dwarf pyramid pears are Doyenné du Comice and Williams' Bon Chrétien with Conference guards, planted 1950-51 and all on Quince A. The dwarf pyramid



EAST MALLING
RESEARCH STATION

March 1954

LARKFIELD PLANTATION
PARK FARM
DITTON FIELDS
CHURCHFIELDS WEST
CHURCHFIELDS EAST
GREAT EAST PLANTATION
EGHAM FIELD
KILN FIELD
MERRYWEATHER FIELD
DITTON LABORATORY
DEADMAN FIELD
NEWGATES FIELD
NEWGATES SHAW
UPPER GRUB
RAILWAY
TO DITTON
TO LONDON
TO MAIDSTONE
TO WEST MALLING
LARKFIELD
SCALE
FEET
100 0
500
1000
1500

cherries and the small apricots are for trial of sprays against Bacterial Canker, and the plums for the study of Silver Leaf. The rows of M.III and M.VIII rootstocks are for infection with fungus diseases and the comparison of fungicides. The Climax strawberries are for various cultural trials : the comparison of spaced rows, matted rows, and matted beds, irrigated and non-irrigated plots, and the effect of burning over or mowing after cropping. A collection of rootstocks is kept here for anatomical work. There is also a trial of foliage sprays with magnesium sulphate and urea applied to dwarf pyramids of Edward VII on M.VII. The effects on symptoms, leaf composition, growth, and cropping are being studied.

E23. A variety of fruit plants are grown here for Pathological and Entomological investigations, including the biology and control of aphids on plums and soft fruit ; tests of spray materials and time of application for Bacterial Canker on Bigarreau Schrecken cherries ; time of application of spring sprays of Bordeaux mixture to Waterloo, Roundel, and Napoleon Bigarreau cherries ; virus inoculation and observation on Early Laxton plums ; virus testing of quince rootstocks ; and Raspberry Cane Spot.

At the south end there are stoolbeds of M.III rootstocks for the study of Apple Mildew and Scab.

E24. This consists of nurseries of potential plum rootstocks ; one set of Pershore seedlings from seeds collected in Worcestershire, and the other of St. Julien seedlings collected in France in 1947. The root anatomy of both families has been examined and a preliminary segregation made into three groups according to vigour. There are collections of *Prunus* and *Pyrus* species for anatomical work, botanical studies, and breeding. In the south-east corner is the wind recording apparatus : a Dine's anemometer and a cup counter anemometer ; the first records wind speed and direction, and the second gives the run of the wind in miles over the recorded period.

E26. This plantation is of strawberries for the study of ' streak ' in Climax, the after-effects of the heat treatment to inactivate virus, and a variety trial including some Cambridge seedlings. The remainder is at present arable.

E27. A part of this plot is a pear rootstock trial of fifteen Merton quince rootstocks (originally collected from the Near East), with the varieties Conference and Dr. Jules Guyot, planted 1941-42. Alongside is a trial of methods for overcoming the incompatibility of Williams' Bon Chrétien on Quince A and C, with Conference pollinators, planted 1941. The methods include normal bridge grafting with Beurré Hardy, bridging with a patch graft of Hardy, and inarching with Hardy on quince. There is also a propagation plot of Mosaic-carrying hop varieties for virus and Verticillium Wilt trials. The rest of the plot is a trial of eight semi-dwarfing plum rootstocks worked with Rivers' Early Prolific and Cambridge Gage, planted 1952.

E28. There is a small block of plums, Purple Pershore on Brompton and Victoria on Myrobalan B, planted 1951, for inoculation with Silver Leaf and subsequent trial of fungicidal injections. The rest of the plot consists of a number of small cherry trials. The north and south headland trees were raised in Australia on ' Kentish Red ' rootstock, commonly used there for bush trees, but which hitherto has proved unreliable here. A trial of reputedly dwarfing rootstocks for cherries includes four acid cherries, a Mahaleb, and a *Prunus serrulata* together with control trees on F12/1, the recommended East Malling clonal Mazzard ; the scion varieties are Napoleon Bigarreau, Frogmore Early, Waterloo, and Noir de Guben. A triple-working trial is composed of bush trees of Noble, high- and low-worked on F12/1, with rings of rind of other species inserted around the F12/1 stem in an attempt to restrict growth. These three cherry trials were planted 1948-49.

The rest of the area is devoted to observation trials planted 1949-50 of sweet cherries double-worked on acid and sweet cherry rootstocks, using intermediates to overcome incompatibility and some to provide, in addition, restrictive effects on growth. The scion varieties used are Early Rivers, Frogmore Early, and Napoleon Bigarreau ; the intermediates are Mazzard F12/1, Carnation acid cherry, and Frogmore Early ; and the rootstocks, four selections of acid cherry *Prunus cerasus*, and two of Mazzard *Prunus avium*.

The frames contain various seedlings and young plants for anatomical work.

E29. This is now arable.

E30. This trial of Williams' Bon Chrétien pears double-worked on Quince A and C was planted 1941-42 ; there is a comparison of four different varieties used as long and short intermediates, and single-worked trees. The pollinators are Conference on Quince C. There is also an apple rootstock trial with half standard Lord Derby and a small block of apple trees, once part of a variety collection, now used for studying the possible effects of weedkillers on the trees. At present MCPA and sodium chlorate are the only treatments.

E31. This old apple variety trial on M.V is now frameworked with Cox's Orange Pippin and Worcester Pearmain.

E32. This is an apple rootstock trial, originally Cox's Orange Pippin and Stirling Castle, planted 1921-22 ; the latter are now frameworked with Worcester Pearmain. The trees were thinned in 1943-44, and some of them were transplanted and dehorned. This plot has been used for many years for trials of sprays to control scab and is now being used for trials of low volume and concentrate spray application.

E33. This is now arable.

E34. This is a trial of new plum varieties, mainly those that have been recommended by the National Fruit Trials at Wisley, on several rootstocks, planted between 1938 and 1949.

E35. This is now arable.

E36. This is a part of the original pear rootstock trial, planted 1920-21 with six varieties on Quince A-G ; it now consists mainly of Conference on Quince A, B, and C, together with a few specimens on the other quinces.

Kiln Field.

This field of 18 acres was bought by the trustees of the Endowment Fund as an established apple orchard in December, 1933. His late Majesty King George VI took part in the ceremony that marked the leasing of the field to the Research Station, when, as Duke of York, he visited the station in 1934. Since then the field has been thinned out, parts have been cleared, and the poorer varieties have been framework grafted to Cox's Orange Pippin and Worcester Pearmain. It was incorporated with the rest of the farm in 1946.

K1. This area is used for Pathology experiments. There are some hops for Nettlehead investigations, Wellington XXX black currants infected with a number of virus diseases for observation, Early Rivers and Roundel cherries, clones from different sources, for investigation of virus status, and Lancashire Lad and Leveller gooseberries for phytotoxicity experiments.

K2. This consists of a block of frameworked Cox's Orange Pippin, Ellison's Orange, and Worcester Pearmain, at present used for studying the effects of continuous water sprinkling in protecting against frost damage.

K3. This is a similar block of trees to K2, some of which are also used for frost work, and some for physiological studies, including abscission and spray damage.

K4. This was formerly a block of Bramley's Seedling ; it was grubbed in 1950, with the exception of a few trees at the extreme south end now used by Biochemistry for mineral analysis of regular and biennial bearing trees. The grubbed area is in use for an investigation of means of restoring soil uniformity after grubbing. Soil analyses were made in the old tree positions and in intermediate positions. The whole was divided into plots to receive deep and shallow ploughing at 18 inches and 9 inches respectively, and high and low rates of manuring, including dung. It was then put down to an arable rotation, the southern half of the area to a three-year and the northern half to a seven-year rotation, finishing with a ley in each case. Following the ley in the third year M.II rootstocks were planted, in direct relation to the old tree positions. These were budded *in situ* with Cox's Orange Pippin and Late Orange. The growth of both rootstocks and maidens is being measured to assess the uniformity of the soil.

K5. This plot contains Miller's Seedling apples used for work on biennial bearing and Barnack Beauty apples for blossom thinning experiments.

K6. This is now arable.

K7. The trees here are Worcester Pearmain under different long-term grass swards sown in 1940 with and without nitrogen and phosphates.

K8. This is now mainly arable.

Newgates Field.

This field of 20 acres was bought in 1927 with funds supplied by the Empire Marketing Board, primarily for propagating clonal rootstocks and soft fruit plants to supply the needs of the Commonwealth as well as those of Great Britain. It was taken into the main farm in 1935.

N1. This area is to be devoted to cherry cultural experiments. It contains at present three small trials of cherries. One of trees on F12/1 to study the effect on the incidence of Bacterial Canker of three methods of tree formation : normal high-working with a single scion at 6 ft. ; grafting a ' staddle ' of F12/1 with several scions after planting ; and frameworking several years after planting, using stub grafts. The second is a pilot trial, planted 1953-54, to provide guidance on the age to grass down the trees in the main cherry trial, which is to be planted in 1956-57. The experimental trees are Merton Heart, and the guard trees Early Rivers, all on Mazzard

F12/1. Trees will be grassed down at 2, 3, 4, 5, 6, and 7 years after planting, with clean cultivation of the control trees. The sward used will be S23 perennial ryegrass and wild white clover, the more vigorous of the swards likely to be used in the main trial. The third is a pilot trial, planted 1953-54, designed to determine the response of cherry trees to different rates and forms of nitrogen starting in the year of grassing down (1957 or 1958). The experimental trees are Merton Heart on Mazzard F1/3, and the guard trees Early Rivers on Mazzard F5/4 and F1/3. Rates of application of nitrogen will be 3, 6, and 9 cwt. sulphate of ammonia and 8 cwt. nitro chalk (equivalent in nitrogen to 6 cwt. sulphate of ammonia). Treatment will be uniform until they are grassed down. The guard trees will provide a broad comparison between F1/3, selected as a possible dwarfing rootstock, and F5/4, the least vigorous rootstock in the old trial on C4.

N2. There are several small strawberry experiments in this area : Royal Sovereign with various widths of matted bed ; Royal Sovereign and Climax for comparison of fertilizer applications in February and immediately after picking ; plots with and without irrigation ; and spray trials for the control of Grey Mould on the fruits.

N3. This contains a plot to supply material for histological work, and a large number of small trials including a block of apples for the study of reciprocal physiological effects of scion and rootstock using M.II, IV, IX, and XVI as stock and scion, together with unworked controls ; apples for physiological studies of fruit bud formation and of spray damage ; pears and plums, double-worked in a number of scion and rootstock combinations, to provide material for histological study of incompatibility ; a collection of apples, pears, and cherries, and various rootstocks to supply material for the Biochemistry Section, including the mineral and organic analyses of leaves ; Lord Lambourne for spindle bush culture and for testing selected stools of MM. rootstocks, Crab C, and M.XII for freedom from chat fruit virus ; and an area for studying the effect of soil management on soil moisture.

N4. This contains a number of annual or short-term strawberry trials : various traps, baits, and other methods for the control of Strawberry Seed Beetle ; the infestation of soil with Strawberry Eelworms, their persistence, effect on cropping, and control ; Strawberry Aphid control and aphid/virus relationships, using *Fragaria vesca* and Royal Sovereign ; and Cauliflower disease inoculation experiments.

It also contains black currants for studying the effect on growth and cropping of Black Currant Yellows and Vein pattern virus diseases ; a few walnut varieties planted in 1928 and 1934 ; *Prunus* and *Pyrus* seedlings for studying the correlation between structure and vigour, and between the structure of tap and lateral roots. There are also three raspberry variety trials including amongst other varieties, (1) Malling Promise, Malling Exploit, Malling Seedling V, Norfolk Giant, and Newburgh ; (2) Amos and New Zealand strains of Lloyd George, Malling Promise, and Malling Exploit ; and (3) Malling Enterprise, Malling Promise, and Norfolk Giant.

Deadman Field.

This 10-acre field was bought in March, 1935, by the Endowment Fund and incorporated in the farm in 1946.

D1. The Victoria plum trees on Myrobalan B are a pruning trial, with two levels of nitrogen. There are unpruned, open-centre, and delayed open-centre trees, to test the effect of these treatments on tree build-up, branch breakage and incidence of Silver Leaf. They were planted in 1949-50.

D2. This is a gage rootstock trial consisting of four varieties of gage, Oullins Golden, Early Transparent, Denniston's Superb, and Cambridge, on six rootstocks, and a comparison of nineteen varieties of gages and dessert plums, mostly on Myrobalan B, Brompton, and Common Plum, for appraisal of their potential value, cropping, liability to fruit splitting, etc. Both trials were planted 1941-42.

D3. This is a Statistics ' uniformity trial ', consisting of Cox's Orange Pippin and Worcester Pearmain on M.VII, planted in 1951, to investigate the variability in the more usual records taken on apple trees, the relationships between such records, and between records that are taken on the growing tree *in situ* and those that cannot be made until the tree is grubbed. Twelve trees of each variety will be lifted every third year. There is also a small nursery trial of pears, Williams' Bon Chrétien, Conference, and Beurré Hardy, on apple rootstocks M.I to M.XVI, Crab C, and Northern Spy, and on Quince A, to investigate the compatibility of such unions.

D4. This is a trial of thirteen clonal pear rootstocks covering a range of vigour, with Quince A as the control ; varieties Williams' Bon Chrétien and Conference. Planted 1948-49 as 3-year-old trees. This field has a windbreak row of damson and bullace varieties.

Merryweather Field.

This 10 acres was planted as a smallholding in 1935, leased by the station in 1937, purchased in 1942 through the Endowment Fund, and incorporated in the farm in 1946.

M1. These staddles of M.VII, planted in 1949-50, are similar to those on G4. They will be used for framework grafting with new seedling varieties.

M2. This consists of Cox's Orange Pippin with Worcester Pearmain pollinators, all on M.IX. It is used for small-scale trials on chemical and biological control, Apple Sawfly control, and the low volume application of fungicides by atomization. Another experiment compares the effects of straw mulch and cultivation on the growth and cropping of stunted trees.

M3. This is now arable.

Newgates Shaw.

This chestnut coppice was formerly on rented land, and has recently been bought for the station. It has been cleared in lanes and planted with walnut and other nut trees.

Upper Grub.

This extreme corner of the station, some 10 acres in extent, was also rented from 1929 until purchased recently with the joint support of the Ministry of Agriculture and the East Malling Research Station Association.

It contains a number of small trials and collections of breeding material, particularly raspberries, seedlings of which are raised under glass and planted out as soon as large enough. Most of them are discarded after a year or two, hence the many gaps in some rows. Promising selections are planted out in six-plant rows for further trial. In addition to red raspberries there are small selections of black raspberries, red/black hybrids, and Boysenberry crossed with Malling Exploit raspberry. Another plot of raspberries is used for a soil management experiment, treatments consisting of straw mulch, sawdust mulch, and clean cultivation, each with high and low nitrogen. The apples, Lane's Prince Albert and Early Victoria (Emneth Early) on seedling rootstocks, are used for observations of Winter Moths. The hops comprise a disease museum of plants with Nettlehead, Chlorotic disease, Split-leaf Blotch, and Mosaic from various sources ; a potash manurial trial ; a field insectary for studying the spread of Nettlehead under field conditions with minimum spraying ; and a trial of seedling hops that appear promising as varieties tolerant of Verticillium Wilt. The crops from varieties selected are submitted for brewing trials. There are three rows of quince rootstocks, 22 clones, for inoculation with a strain of *Verticillium dahliae* isolated from pears on quince rootstocks in the West Midlands, to study possible variation in resistance to the fungus. There is a collection of fruit species and varieties for insect vector observations. The strawberries are for the study of aphid preference for leaves of different ages and for checking sampling methods.

Churchfields East.

This 20 acres was bought in 1926 with funds made available by the winding up of the Hop Control Board.

C2. This is an apple manurial trial (nitrogen, potash, and phosphate), planted 1930-31 with 2-year-old trees after cereal crops had been grown for four seasons without fertilizers. Originally there were 9-tree plots of Cox's Orange Pippin and Beauty of Bath, but now only the central tree, Cox's Orange Pippin on M.XII, remains. Double guard rows of Worcester Pearmain on M.IX run between the plots in both directions. Since 1953 half the plots have been grassed down, and the effects of these treatments on the crops and storage quality of the fruits are being investigated.

C3. This was originally a trial comparing a number of vigorous Malling rootstocks with layered ' free ' stocks and seedling Crab, using Lane's Prince Albert as the scion variety. Many of these trees have now been used as frameworks for testing out new seedling apple varieties. After a preliminary selection had been made from the seedlings grown as cordons, such as those on G18, all the available one-year wood of each variety was framework grafted on to one of these old trees. By now all have been used and the M.VII rootstocks on G4 were planted for future use and to avoid the risk of virus infection. Also included is a rootstock trial of Allington Pippin on clonal ' free ' and vigorous Malling rootstocks, a comparison of three methods of topworking and one method of frameworking Laxton's Superb on Newton Wonder trees, and a layered ' free ' pear stock trial with the scion variety Dr. Jules Guyot.

C4. This was originally a sweet cherry rootstock trial planted 1928-29 with Early Rivers, Bigarreau Schrecken, and Turkey Heart on a number of clonal Mazzard rootstocks in an attempt, which proved unsuccessful, to find cherry rootstocks with a wide range of vigour. F12/1 is now widely used and recommended because of its vigorous growth, good nursery behaviour, and resistance to Bacterial Canker. A tree of Turkey Heart on F12/1 may be seen near the middle of the south edge of the plot, row 6 tree 2, next to a tree on F5/4, row 7 tree 2, the most dwarfing of the selections in the trial. The plantation is now being used to study the effect of virus diseases on growth and cropping.

C5. This field contains a number of trials. The Climax strawberries are used for studying methods of control of ground beetle, the biology and control of Strawberry Aphids, transient yellows, and the effect of irrigation on soil temperatures ; there are also two strawberry variety trials. There is a small plot of plums and cherries inoculated with a number of virus diseases. The apples are in two trials : Winston and Melba on M.VII and M.IX for experiments on biennial bearing, and Winston on M.VII and M.IX for studying rootstock effect on spur behaviour and blossoming. There is a trial of hop varieties tolerant of Verticillium Wilt, and a propagation plot started in 1950 for ' building up ' stocks of certain new hop varieties. There are four varieties of cherries, Merton Heart, Merton Bigarreau, Early Rivers, and Napoleon Bigarreau, infected with five virus diseases, for comparison of their growth and cropping with that of control trees free of virus.

All the land west and north-west of Churchfields East forms the Bradbourne Estate of 200 acres acquired in 1938 with money raised by public subscription, to which the Ministry of Agriculture also subscribed on a pound for pound basis.

Churchfields West.

C6. This is a walnut variety trial planted with the younger trees from the collection in Newgates, at that time mostly 10-12 years old.

C7. This is a walnut variety trial planted in 1941-42, mostly with 3-year-old trees.

C8. This consists of Laxton's Fortune and Sunset apples on M.IX, planted 1945-46, which are being grown in preparation for future experiments and in the meantime are being calibrated.

C9 and 10. This is a field trial of the new rootstocks (see G11) bred for Woolly Aphid resistance, with control trees on some of the standard Malling rootstocks and on two resistant rootstocks used in the Commonwealth, Northern Spy and Ivory's Double Vigour. Four of the resistant ones, MM.104, MM.106, MM.109, and MM.111, have been selected for use in this country, together with a fifth, somewhat less resistant, that has been added to the Malling rootstocks as M.XXV. The trees on each rootstock are in groups of three, one being worked with Jonathan, chosen because it is early bearing and widely grown in Commonwealth countries, one with Cox's Orange Pippin, the most important English variety, and another with Ellison's Orange, chosen because its cropping is less affected by spring frosts. Fifteen have been selected and numbered in the Malling-Merton series, and trees on these are labelled. C9 contains those considered, on the basis of their root anatomy, to be semi-dwarfing and intermediate in vigour, and C10 contains trees on rootstocks expected to be vigorous or very vigorous. These plots were planted in 1945-46 and the regulated method of pruning has been used to induce early cropping. Starting at row 1 tree 23 in C9 and in each case selecting the tree of Cox's Orange Pippin, M.IX, M.VII, MM.106, and MM.104 can be seen close together, with M.IV close by at row 3 tree 20. In C10, M.II and MM.109 can be compared, tree 6 in rows 3 and 4, while MM.111 is tree 6 in row 8. M.XXV can be compared with M.XVI, row 1 tree 6 and row 3 tree 9.

C11. This consists of apples on M.II and M.IV, planted in 1945-46, and grown for five years without experimental treatments in order to ' calibrate ' the trees, after which, in 1951, two trials were started on alternate strips. There are two experimental trees in each plot, the remainder being guard trees. In one experiment, with Laxton's Superb on M.II as the experimental trees, three strips of experimental plots are used for the comparison of (i) straw mulch, applied in October at 8 tons per acre initially, with subsequent annual applications of 4 tons per acre ; (ii) permanent sward of S23 perennial ryegrass and wild white clover, and (iii) cultivation with autumn weeds. Half the plots receive sulphate of ammonia at a low rate, 3 cwt. per acre, and half at the higher rate of 6 cwt. per acre. Soil moisture tensiometers are installed on some of these plots. The three alternate strips, with Laxton's Fortune on M.II as the experimental trees, are for the comparison of S23 perennial ryegrass and wild white clover sward with those following the use of five other grass or clover seed mixtures all receiving high nitrogen (6 cwt. of sulphate of ammonia per acre).

C12. This consists of Laxton's Superb and Worcester Pearmain apples on M.IV, planted 1945-46 for use eventually in connection with work on biennial bearing. There are three pruning treatments : open-centre and delayed open-centre trees, both with established-spur pruning, and regulated trees.

C13. This consists of Cox's Orange Pippin and Laxton's Superb on M.II, planted 1945-46, also for biennial bearing experiments. There are five pruning treatments : open-centre trees with established-spur and renewal pruning ; delayed open-centre trees with established-spur and renewal pruning ; and regulated trees. The first 3 trees in rows 1, 2, and 3 were deblossomed for 6 years and bore their first crop in the seventh, to determine the effect of the pruning treatment on tree size without the interaction of cropping.

C14. These apples on M.II form the final stage in the selection of some new varieties bred at the station, including Late Orange, Early Worcester, and Michaelmas Red, interplanted with standard varieties. A part was planted 1946-47 and the rest two years later.

C15, 16 and 17. These contain trials, planted 1946-47, of new apple rootstocks raised at East Malling by crossing M.IX with other Malling rootstocks. The new rootstocks were grouped as far as possible in the vigour groups anticipated from a study of their root anatomy : C15 vigorous, C16 intermediate, and C17 dwarfing. The scion varieties include Ribston Pippin, Orleans Reinette, Cox's Orange Pippin, Egremont Russet, and Sunset. The full range of rootstock effect is illustrated by comparison of trees on rootstocks 3426, 3431, M.IX, 3436, M.VII, 3428, M.II, 3438, M.XVI, and 3430.

Ditton Fields.

This ten-acre field is now arable, after more than ten years as a rootstock nursery.

Park Farm.

This land forms the part of Bradbourne Estate between Churchfields and the road from East Malling to Larkfield, and consists of several fields with a total area of 115 acres. Small areas of these fields are usually occupied by isolated-block runner-beds of strawberries.

P1. In a corner of this field there are stoolbeds of re-cloned virus-tested Malling rootstocks.

P2 and 3. This area will, during the next few years, be planted up with the experimental nurseries ; they are moved in a long-term rotation through the lower fields around Bradbourne House. The material planted on P3 is ready for budding in the summer of 1954.

P4. This is arable at present.

P5. This is an observation plot of fruit varieties for a study of frost susceptibility.

P6. This contains trials of propagation by cuttings, apple seedlings under selection for late flowering, and Mosaic-susceptible hops, layered to provide healthy material for virus experiments.

P7. This is a grass paddock.

P8. This contains stoolbeds of MM. apple rootstocks, with on the west side, stool and layer beds of a range of Malling rootstocks.

P9. This contains a trial of plums on a number of the less vigorous rootstocks with the scion varieties Early Laxton, Victoria, and Cambridge Gage, with Marjorie's Seedling in the guard rows. It was planted 1948-49. There is also a comparison of the East Malling clone of Loganberry with the Thornless Loganberry and a trial of two different methods of training them likely to have lower labour requirements than traditional methods.

P10. The plot of Worcester Pearmain and Cox's Orange Pippin apples on M.VII is in use for a trial of the long-term influence of sprays on the population of pests such as the Fruit Tree Red Spider Mite and on predators. The Lane's Prince Albert, Laxton's Fortune, Sunset, Grenadier, and James Grieve apples, Victoria and Czar plums on Michaelmas Prune, and Laxton's Superb, Conference and Fertility pears on Quince C are retained for future entomological trials.

P11. On this plot there is a row of plums for a tree-forming trial ; the four treatments are summer-pruned dwarf pyramids, half-standards with and without hormone treatment to induce wide crotch angles, and unpruned trees, to determine whether summer pruning prevents branch breakage to the extent suggested by the original pilot trial.

P12. This contains blocks of apples, pears, cherries, plums and gooseberries, and black currants for phytotoxicity trials.

P13. This contains fruit virus trials and an observation plot. It is possible here to see symptoms of most of the recognized virus diseases of top fruits, and the effect of cherry viruses on the vigour of F12/1 clonal Mazzard rootstock (cf. K1). There are also cherry trees infected with different strains of the same virus for investigating cross protection between strains and effects of strains on rate of growth.

P14. This is the experimental nursery ; it consists of various small trials of propagation techniques and rootstock/scion compatibility. This area will be gradually cleared and transerred to P3.

P16. This is a museum plot containing short rows of stool or layer beds of all the rootstocks described or raised at East Malling. A study of root formation is also in progress on seedling apple stools and various clones of Pershore plum are being compared for rooting. The hedges of Myrobalan B, Brompton, and Crab C are used to supply shoots for hardwood cutting experiments.

P17. This is arable at present.

Sports Ground.

There are two hard tennis courts given by the East Malling Research Station Association, and a cricket ground whose outfield is used for hockey in winter. The sports pavilion was built with money subscribed jointly by members of the Association and members of Staff.

Bradbourne Gardens.

The fine walls of the old garden of Bradbourne House, and the land within and adjacent to them, have been planted with fruit for a few small trials and to demonstrate the value of research work done at the station when applied to private gardens or small intensive plantations.

B1. The southern half of the central part is planted with apples, the northern half with pears ; there are two main tree types, oblique cordons and dwarf pyramids. The apples are mostly on M.IX and M.VII, the pears on Quince A and C. A few dwarf pyramid apples in the outer rows are on some of the new ' M.IX Cross ' rootstocks (see C15, 16, and 17). The southern half of the central walk is flanked by double U cordon apples on M.VII ; the first tier of branches was produced by inserting two buds at 1 ft. above the ground. The northern half of the walk has pears trained on the Le Page arcure system. The paths on the west and east sides are bordered by three-tier espalier apples and pears. On the walls facing south and east are a number of vertical cordon pears, mostly high quality and late-ripening varieties. On the other walls is a rootstock trial of fan peaches, trained uniformly ; two varieties, Peregrine and Sea Eagle ; stocks, Brompton, Common Mussel, St. Julien A. and St. Julien C. In the south-east corner is a block of dwarf pyramids on M.II of late-flowering apple varieties likely to be useful in gardens situated in frost pockets. On the fence there is a collection of gooseberries trained as U cordons. The Cox's Orange Pippin trained as a winged pyramid in the south-west corner is on Crab C and was planted in 1946-47. The main block of apples and pears were planted 1944-45, the wall peach trial 1946-47.

B2. The fan peach trial is continued round this wall. The rest of this area is occupied by bush peaches on Brompton, for comparison of a summer and a winter pruning method. The varieties are Hale's Early, Peregrine, Libra, Barrington, and Bellegarde. They were planted 1948-49.

B3. This contains apple seedlings on their own roots. Seedlings from King of the Pippins× *Malus zumi* to study the segregation of frost resistance, and seedlings obtained from crosses of Worcester Pearmain, Cox's Orange Pippin, and Ellison's Orange, already selected on the basis of susceptibility or resistance of the seedling plants to frost damage, to test the value of this early selection as a guide to the subsequent behaviour of blossoms.

B4. This consists of the demonstration fruit gardens, two of 5 rods and one of 11 rods, designed as suitable for incorporation in private gardens. They were planted 1943-44. A collection of Morello cherry varieties is fan-trained on the wall.

Arboretum.

B5. This is a collection of apple, pear, plum, cherry, and quince rootstocks grown into trees to show their botanical characters and natural habit.

B6. This area contains a number of walnut species and sub-species.

Lake Delta.

B7. The soil of this artificial island was removed from the bottom of the lake when it was cleaned out in 1948-49 and built up above the level of the water in a series of terraces so that the surface ranges from 1 ft. above water level to 2 ft. 6 in. It is used for experiments on the rooting of cuttings. Because of the highly alkaline soil, manganese deficiency occurs and small-scale spraying trials are in progress. The water level in the lake is maintained by a sluice at the north-east end.

Larkfield Plantation.

This occupies the eastern part of the bank at the western extremity of the station's land, adjoining Larkfield village. Here are duplicates of some of the trials on Churchfields West, on a light soil very different from that of the rest of the Station.

L1. This consists of Laxton's Fortune and Sunset apples on M.IX (duplicate of C8, q.v.). At the top, there are a few Bramley's Seedling and Cox's Orange Pippin apple trees, each worked on three M.IV rootstocks, in an attempt to improve anchorage.

L2. This consists of Cox's Orange Pippin and Worcester Pearmain apples on M.IV. They are being grown in preparation for future experiments and in the meantime are being calibrated.

L3. This is an apple rootstock trial with the semi-dwarfing and intermediate members of the Malling-Merton series (duplicate of C9, q.v.).

L4. This is an apple rootstock trial with the vigorous and very vigorous members of the Malling-Merton series (duplicate of C10, q.v.).

L5 and 6. These are apple pruning trials (duplicates of C12 and 13, q.v.).

L7. These apple trees are Laxton's Superb on M.II now being used for comparison of the effect on tree performance of maintaining three soil moisture levels, and the natural soil moisture of the control plots.

The Laxton's Fortune on M.II are used for the study of the interdependence of water and nitrogen for maximum growth and cropping. Certain trees of Laxton's Superb and Laxton's Fortune on M.II are so unthrifty that a pilot trial is being carried out to compare the value of watering, mulching with farmyard manure, and deblossoming as means of bringing such trees into growth.

L8. This consists of a row of small plots of grasses and other species of possible interest for cover cropping, and a soil management trial. Each block in the trial contains a central Worcester Pearmain apple tree as pollinator, surrounded by eight experimental plots, one with no tree continuously cultivated to keep it free from weeds, the others each with one tree of Cox's Orange Pippin, receiving one of the following treatments : continuous cultivation, straw dug in, farmyard manure dug in, autumn weeds, a winter cover crop of oats and tares turned in during May, a natural sward, a sown sward of S23 perennial ryegrass and wild white clover. The trees are all on M.VII and were planted in 1946-47. Half the blocks receive fertilizer applications in addition to other treatments. The effect of these treatments on soil structure, organic matter, and root distribution is being studied. A few similar trees are being used for preliminary observations on the suitability of a number of sward mixtures sown in 1949 for use as cover crops, including a plot receiving a heavy straw mulch at the rate of 8 tons per acre per annum. Comparisons are being made with the plots in the main trial. Rows 9 to 12 were planted 1949-50 for trying out further sward mixtures in 1955.

Summary.

This catalogue of the experimental plots briefly describes the chief experiments in progress, calling attention to the treatments and some of the effects that can be observed.

PRUNING YOUNG APPLE TREES BY THE REGULATED METHOD

By A. P. PRESTON

Considerable interest has been shown by growers during recent years in the regulated method of pruning apple trees. It is one of several methods included in the new pruning trials at East Malling. It has also been used for the trials of the recently released Malling-Merton apple rootstocks. Although it is not a new method, few, if any, detailed directions have been published describing how trees are pruned during the early years by the regulated method. This bulletin is written in response to requests from growers ; it is based upon notes made by the writer each year at the time the trees were pruned.

Pruning method.

First year.

The maiden trees were headed back to approximately 30 inches from ground level. Feathers were cut hard back, taking care not to remove the secondary buds on either side of the base of each feather by cutting into the wood of the trunk. A bud 10 inches below the topmost one was notched to ensure that a shoot grew out sufficiently low down to form the lowest branch. Shoots that grew from buds below the notched bud were rubbed out ; all the others were allowed to develop naturally and no selection of shoots was practised. Any flower trusses were removed leaving the leaf cluster intact. Some trees were also grown without notched buds.

Second year.

Three of the strongest shoots were tipped removing from one half to one third of their length, and an even balance between the three tipped shoots was secured. Other shoots were left unpruned

Third year.

No more than three of the strongest growing branches had their leaders tipped, being pruned to the same degree as in the previous year ; this was mainly to balance the tree and avoid lop-sided development. Frequently it was necessary to cut only one leader. No laterals were shortened, but thinning out of branches was necessary with some varieties.

Fourth year.

No leader tipping was done. Laterals were not shortened but unwanted shoots were removed completely by cutting them back to the parent branch. Laterals that competed with the unpruned leaders were also removed.

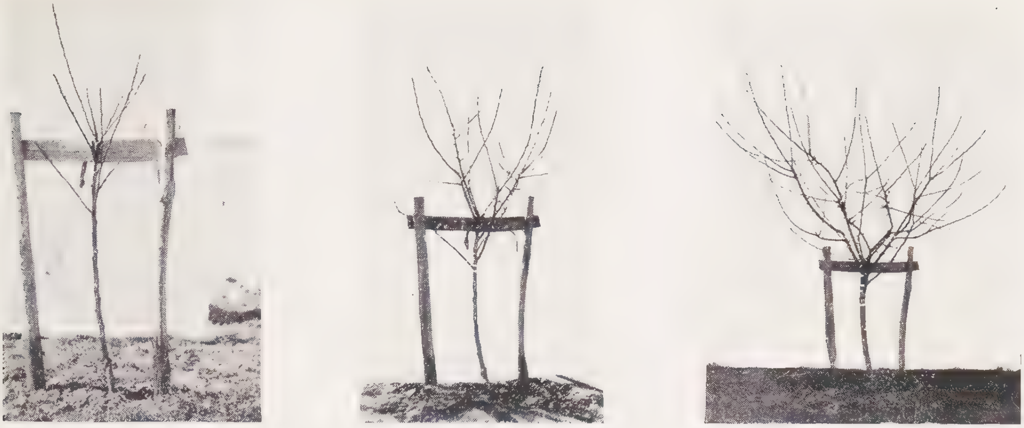
Fifth year.

The treatment was the same as for the previous year. Some older branches, mainly weak ones that had fruited, were removed. A considerable amount of thinning out of one-year laterals was necessary on very vigorous growing trees.

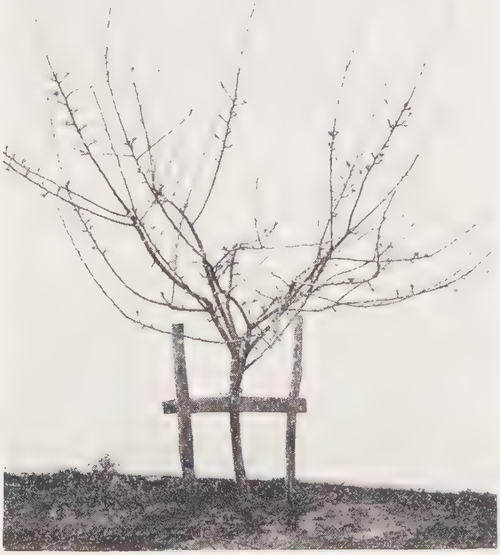
Sixth, seventh and eighth years.

Pruning was simple and straightforward ; no leader tipping or shortening of laterals was done, but crowded, weak, or shaded branches, irrespective of age, were cut out completely. Laterals that competed with the unpruned leaders were removed. A visit to the trees just before fruit picking showed those branches that were carrying less well coloured fruit, due to shading ; these were cut away in the following winter.

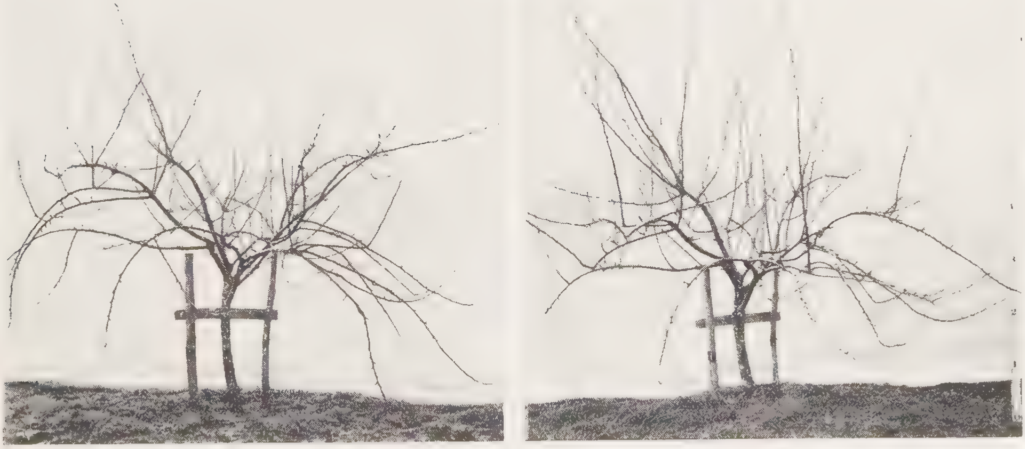
Photographs of a regulated tree of Cox's Orange Pippin on M.II taken after pruning each year up to the seventh year are shown in Fig. 1.



Second year. Third year. Fourth year.



Fifth year.



Sixth year. Seventh year.

FIG. 1.

Photographs of a regulated tree of Cox's Orange Pippin on M.II taken after pruning each year.

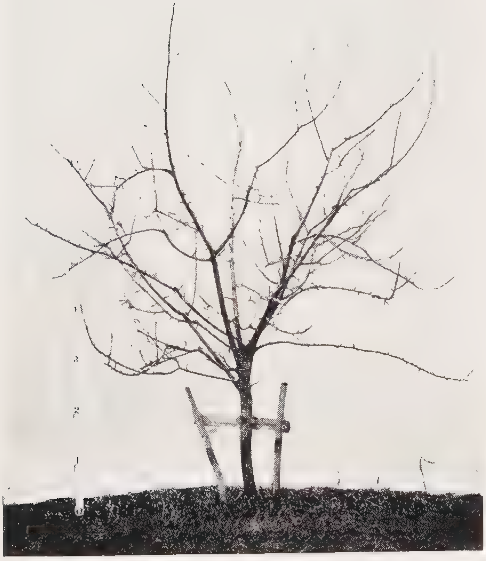


FIG. 2.
Seven-year-old Regulated tree of Worcester Pearmain on M.IV after pruning.

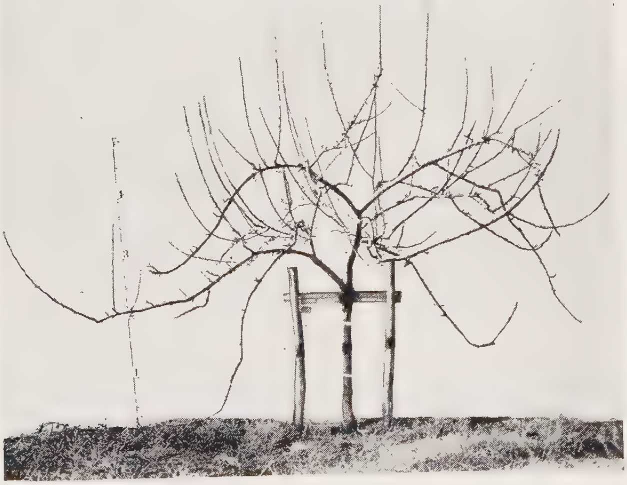


FIG. 3.
Nine-year-old Regulated tree of Cox's Orange Pippin on M.IX after pruning.

Fruit yield.

Trees pruned by the regulated method have yielded very satisfactorily and, up to the time of writing, when most of them are nine years old, the size of fruit has been well up to market requirements without fruit thinning. This has been under conditions of clean cultivation with autumn weeds allowed to grow. Due, no doubt, to the low, spreading shape of most varieties when pruned this way and their habit of bearing fruit on long laterals, fruit colour has been excellent.

The annual fruit yields from regulated trees of Cox's Orange Pippin on a wide range of rootstocks show clearly that it is possible to bring trees of this variety on very vigorous rootstocks, such as M.XVI, into bearing almost as early and as heavily as those on M.II (Table I). Even heavier yields have been obtained from comparable trees of similar size on some of the new rootstocks.

The yields from regulated trees of Worcester Pearmain on M.IV have also been very satisfactory. One of these trees after pruning is shown in Fig. 2.

TABLE I.

ANNUAL YIELDS PER TREE (LB.) FROM REGULATED TREES OF COX'S ORANGE PIPPIN ON A RANGE OF ROOTSTOCKS. TREES PLANTED 1945-46.

Rootstock.	1948.	1949.	1950.	1951.	1952.	Total.
M.IX	4	14	16	13	25	72
M.VII	3	9	40	20	73	145
M.II	2	4	24	23	58	111
M.XVI	0	2	29	7	58	96

General considerations.

At East Malling the lightly pruned regulated tree has proved capable of yielding heavy crops of fruit at an early age, the heaviest recorded being one of 5 bushels 14 pounds from a seven-year-old tree of Ellison's Orange in 1952. The relatively large number of fruits carried most years has considerably reduced the tendency for them to be too large and of poor quality as is so common with crops from young trees pruned along more orthodox lines.

Most of the regulated trees at East Malling are now nine years old and it is clear that this method of pruning may be applied with confidence by growers to temporary or filler trees, since the main object in planting such trees is to secure early and heavy crops of fruit within ten years or so from planting. Even trees on the dwarfing rootstock M.IX, while lacking an orthodox tree framework (Fig. 3), have cropped well for their size (Table I). Further work and experience is necessary, however, before the regulated method can be recommended for use on trees that are intended to be permanent. It is hoped, however, that some growers will try the method on a limited scale on trees that are to be permanent so that information may be obtained on tree behaviour with this light method of pruning under different conditions. Where trees are being planted as maidens to remain permanently it would be advisable at the outset to secure wide crotch angles for the primary branch framework, and the first year's pruning, as outlined above, should be modified to include the selection of shoots when they are not less than four inches long, as recommended on page 199 of the Annual Report for 1951.

No experiments have yet been made to determine the manurial needs of regulated trees. It does seem desirable, however, to manure them more generously than usual, because of the number of fruit buds they carry and the crops of fruit they yield ; in fact, they probably need a ' production ' ration in addition to a ' maintenance ' ration.

Dessert apple varieties which have recently been pruned by the regulated method are Beauty of Bath, Cox's Orange Pippin, Egremont Russet, Ellison's Orange, Harvest, Jonathan, Late Orange, Laxton's Superb, Michaelmas Red, Orleans Reinette, Ribston Pippin, Sunset, Tydeman's Early Worcester, and Worcester Pearmain. All these varieties have responded well, and only with Ellison's Orange, on a sandy soil, was branch breakage at all severe : this was probably due to the heavy crops carried on weak shoots formed during the severe droughts of the summers 1947 and 1949.

Summary.

An account is given of the year-to-year pruning treatments used recently at East Malling in growing regulated apple trees.

BACTERIAL CANKER, LEAF SPOT, AND SHOOT WILT OF CHERRY AND PLUM

By J. E. CROSSE

Among the important economic plant diseases of Great Britain Bacterial Canker and Leaf Spot of stone fruits rate high. Although the cause of the disease and its main features have been known for over twenty years, they are still not always fully understood. This has led in some instances to the misapplication of recommended control measures and in others to the use of measures which, from the very nature of the disease, have no hope of succeeding. The following account brings up to date our knowledge of the disease in the light of recent research and is primarily intended to draw attention to the more important points to be considered in carrying out control measures.

The bacteria responsible.

The bacteria attacking stone fruits in this country belong to the genus *Pseudomonas*, a versatile and highly successful group of bacteria, including many soil and other saprophytic forms in addition to plant and animal pathogens.

Two closely related but distinct species are involved. The first, *Pseudomonas mors-prunorum*, is responsible for most of the bacterial diseases of cherry and plum, and in host range and distribution is by far the most serious parasite of *Prunus* species in Great Britain. It appears to be limited to plants of this genus, and in addition to cherry and plum it has been found attacking acid cherry, myrobalan, peach, apricot, almond, and the purple-leaved plum (*Prunus pissardii*) ; recently it has been found on *P. triloba* and *P. sibirica*. The second species, *Pseudomonas prunicola*, occurs occasionally on cherry where it causes a leaf spot and canker similar to that of *Ps. mors-prunorum*, and on plum, where its activities are limited to the young green extension shoots. In isolated cases it also causes an epidemic blossom blight of pear. It is now believed that *Ps. prunicola* is identical with, or a special form of, *Ps. syringae*, the lilac blight organism. *Ps. syringae* is widespread in certain parts of the U.S.A., where it is a major pathogen of stone fruits. *Ps. mors-prunorum* does not occur in that country but has been reported from Scandinavia and Australia.

The seasonal cycle of the disease.

On cherry, plum, apricot, and other hosts, there is a well-defined seasonal cycle in which a winter canker phase alternates with a summer leaf phase. The salient features of this seasonal cycle are shown diagrammatically in Fig. 1.

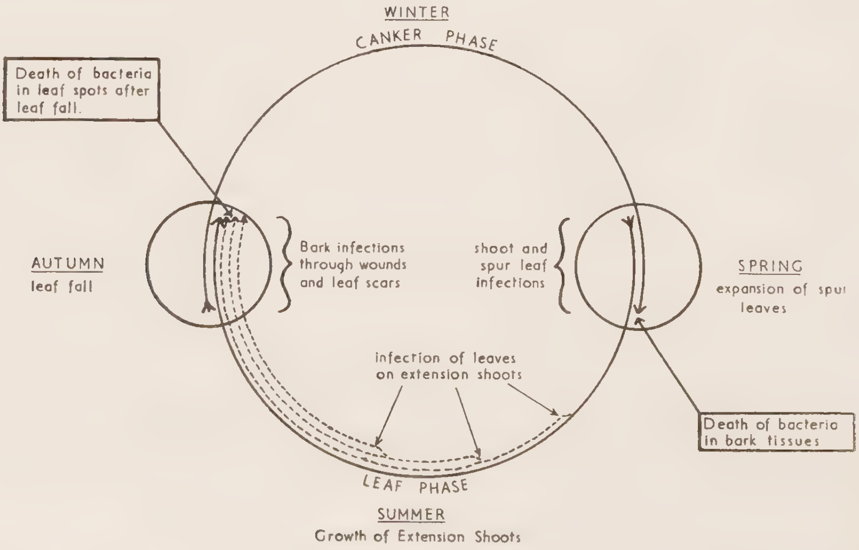

WINTER
CANKER PHASE
Death of bacteria in leaf spots after leaf fall.
AUTUMN
leaf fall
Bark infections through wounds and leaf scars
shoot and spur leaf infections
SPRING
expansion of spur leaves
infection of leaves on extension shoots
Death of bacteria in bark tissues
LEAF PHASE
SUMMER
Growth of Extension Shoots

FIG. 1.
Seasonal cycle of the disease.

The winter phase (Bacterial Canker).

This is the economic phase of the disease causing amongst other symptoms the familiar ' die-back ' and gummosis. It begins in autumn with an attack on the living bark of the stem and branches. Throughout the winter months the bacterium spreads slowly through these tissues, killing and disintegrating them. In spring, as the buds break, the rate of spread increases rapidly, and considerable areas of the bark may ultimately be invaded. In early summer, for reasons not fully understood, the bark tissues become resistant, further spread ceases, and the bacteria die out in the infected tissues. These become sealed off and callused over, and this normally marks the end of the winter phase of the disease. The cankers are not, therefore, normally perennial, i.e. they do not increase in size from year to year unless they become reinfected. Live bacteria may persist, however, in buds that have been killed over winter or in the spring. During the summer the bark tissues remain resistant and it is impossible to establish infection by artificial inoculation. In autumn, with the approach of the dormant period the summer resistance breaks down and the bark becomes once more susceptible to infection.

The summer phase (Leaf Spot).

Before the bacteria die out at the end of the winter phase the young leaves become infected, resulting in the familiar leaf-spotting. On reaching maturity leaves are no longer readily infected, and there is thus no accumulation of infection on individual leaves in the ensuing months. Two types of leaf infection can be distinguished :

(*a*) *Spring infections* of the spur leaves from cankers and infected buds on dead spurs.
(*b*) *Summer infections* of leaves on extension shoots from infected spur leaves and also, probably, from bacteria persisting in infected buds.

As the leaf spots increase in age the bacteria in them tend to die out, particularly in a dry season. By the end of summer there are usually more live bacteria in the later-formed spots on extension leaves than in those on spur leaves. The extension leaves therefore probably provide the bigger proportion of bacteria for the autumn infection of the stems and branches.

In wet weather bacteria ooze out of the spots and are splashed about the tree. When the leaves dry many bacteria, inactive but alive, are left attached to the leaf surfaces and in this state there may be as many as half a million per leaf on unsprayed cherry trees in October. It is estimated from this that the total leaf surface populations on a five-year-old tree may be something of the order of five hundred million ! This figure gives some idea of the magnitude of the problem involved in combating the autumn infection.

During rain the bacteria are washed off the leaves and find their way into wounds and leaf scars to initiate once again the winter phase. These leaf surface populations remain at a high level even in a wet autumn. Bacteria washed off are therefore continually replaced, mainly, it is believed, from the leaf spots. These, however, may not be the only source of replacement ; recent evidence suggests that under suitable conditions the bacteria can multiply on the leaf surface, utilizing nutrients exuded by the leaves.

Because of its apparently small economic importance the leaf phase of the disease is often disregarded. While the precise relations between it and the canker phase are not yet fully understood, there is no doubt that in cherry at least it plays an important part in maintaining the disease cycle. It has been found that control of the leaf spot by spring sprays will also to some extent control the winter canker phase.

Symptoms of the winter canker phase.

Symptoms resulting from autumnal bark infections do not become obvious until early summer of the following year, by which time this phase of the disease is virtually over. On the younger branches and stems, where the bark is relatively thin, the dead areas become conspicuous as shallow depressions or cankers, resulting from the renewed growth in thickness of the surrounding healthy tissues, but on older branches, where the bark is very thick, the only sign of infection at this stage may be gumming. If a cut is made across the edge of the canker a sharp line is usually found to separate the green healthy tissues from those which are brown and diseased.

If a canker girdles a branch or stem, ' die-back ' results. Symptoms of this may appear at any time during the growing period depending on the size of the branch or stem and when it was girdled. If girdling takes place early in the winter the buds may fail to break, or wither soon after breaking. Alternatively, the leaves may develop but remain small, yellow and rolled. With comparatively late girdling, symptoms may be delayed long after the bacteria in the canker have died out. The development and colour of the leaves in such cases is at first normal ; on young cherry the first signs of disease, a rolling of the leaves, may not appear until mid-season. Associated with this there is usually a swelling of the branch immediately above the diseased area, due to the accumulation of food material translocated down from the leaves. On larger branches changes in leaf colour and premature leaf-fall are often the first indication of impending death, which may not actually occur until the following spring or summer. The late occurrence of ' die-back ' has given rise to the widespread but mistaken belief that the bacterium remains active in the bark throughout the growing season. This is untrue, and the cutting out of affected branches which this belief prompts has little to commend it from the point of view of direct control of Bacterial Canker, though probably still desirable at this stage in our knowledge.

The symptoms described so far are the most spectacular and those most widely known. Their absence, however, does not necessarily mean an orchard is free from the disease, for there are other, and far less conspicuous symptoms, which are easily overlooked. In cherry these are usually associated with the fruiting spurs or the nodes on the one-year-old wood which may be killed outright (Fig. 2), or become only partially infected. In the latter case there is usually a minute canker under one of the leaf scars, which may be too small to impair the normal development and survival of the spur or nodal buds. Apart from a tendency for the leaves to take slightly longer than normal to develop fully, such partially infected spurs or nodes often appear quite healthy (Fig. 3).

These minor symptoms are not common on plum so far as is known. On cherry, however, they are undoubtedly widespread. Though of no immediate economic importance, they play an important part in maintaining the disease cycle until such time as the more serious symptoms may appear.

How do the bacteria gain access to the bark tissues?

Because of their extremely small size bacteria are well adapted to penetrate even the smallest wounds. Any damage to the protective bark by pruning, cultivation, or insects, etc., is liable to infection, especially if the damage is done during the autumn. Wounds made during the summer resistance period are usually safe. Even these, however, have been known to become infected in the autumn, possibly through growth cracks, or where healing is incomplete.

In cherry trees infection of crotches is common through natural crevices resulting from growth in thickness of opposing branches, particularly on older trees. Crotch cankers are often very serious and may lead over a period of years to the progressive killing of the whole tree.

The most important avenues of infection in cherry are the leaf scars. These natural wounds are formed in abundance in the autumn, i.e. at the very time when infection is most likely. Leaf scar infection has been occasionally noted on a few plum varieties, e.g. Victoria, Reeves Seedling, and Monarch, but does not appear to be so important on this crop as on cherry.

Leaf scar infection.

In the rain and high winds of autumnal gales, leaves are torn off and bacteria washed from the leaf surfaces on to the freshly formed scars. The bacteria are immediately sucked into the wood vessels that had supplied the leaf (Fig. 4) and may penetrate into the heart of the spur, setting up a deep-seated infection. By January or February the spur is often dead and the infection spreading to the branch to form cankers. In the mildest forms the infection may remain localized near the leaf scar and never spread far enough to affect the development of the buds the following spring. This results in the symptomless or nearly symptomless, but nevertheless infected, spurs and nodes already described.

In view of the number of scars formed in the autumn and the quantity of bacteria available from the leaves, it is perhaps surprising that so comparatively few spurs become infected. There are three main reasons for this : firstly, infection is intimately bound up with weather conditions. Rain is essential for transferring bacteria from the leaves to scars, so that scars formed during dry windy weather tend to escape infection. Secondly, as inoculation experiments have shown, the bulk of the scars, i.e. those formed at the end of October and beginning of November, are not readily infected. It is believed, therefore, that most natural infections take place through scars formed earlier in the season by the fall of occasional leaves from September onwards. Finally, the entrance of bacteria into the scars does not necessarily result in infection. Before this takes place the numbers of bacteria entering must exceed a certain minimum or ' threshold ' number.

This last point emphasizes the importance of maintaining the leaf surface population at a low level. It is probably for this reason that, in the case of cherry, spring sprays have a controlling effect on autumnal infection.

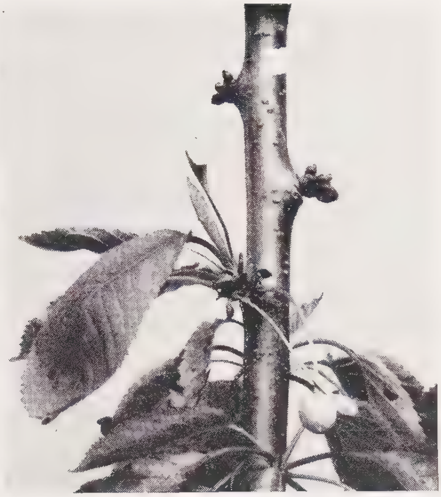


FIG. 2.

Dead spurs on Napoleon cherry resulting from leaf scar infection the previous autumn.

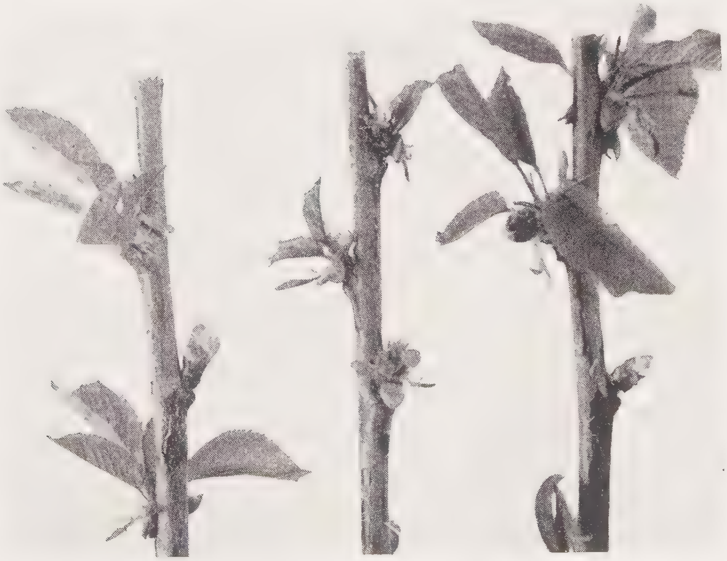


FIG. 3.

Partially infected nodes on one-year-old wood of Napoleon cherry. With the exception of two (top right), all are infected in the leaf scar below the bud. Note delayed development of otherwise healthy buds. Some of the infected nodes are almost indistinguishable from healthy ones.

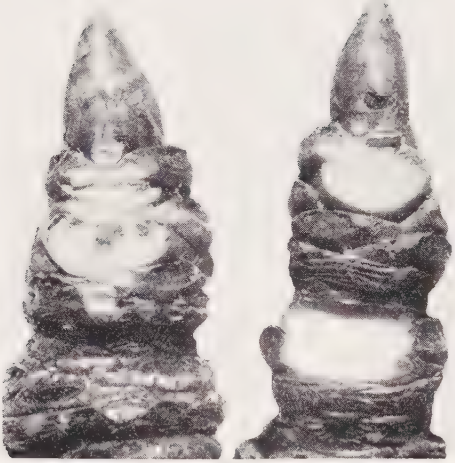


FIG. 4.

Right, healthy spur ; *left,* diseased. The diseased spur shows early stage of leaf scar infection resulting from artificial inoculation. At this stage, December, the disease is still confined to the wood vessels which had originally supplied the leaf. Later this usually spreads to the whole spur and thence, by the spring, into the branch tissues.

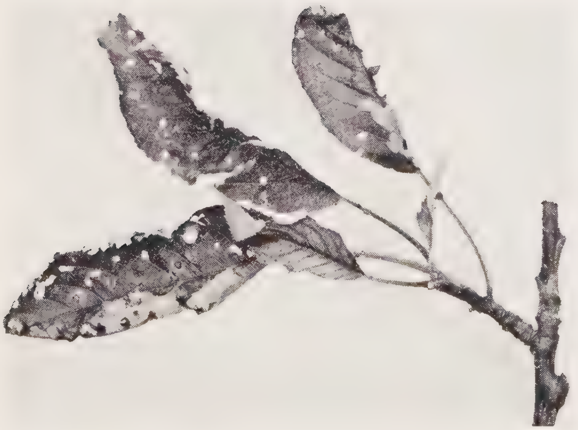


FIG. 5.

Early stage of spur wilt of cherry. The arrow indicates the blackening and killing of current year's spur growth which precedes collapse of the leaves (see Fig. 6). Note severe leaf spot associated with this.

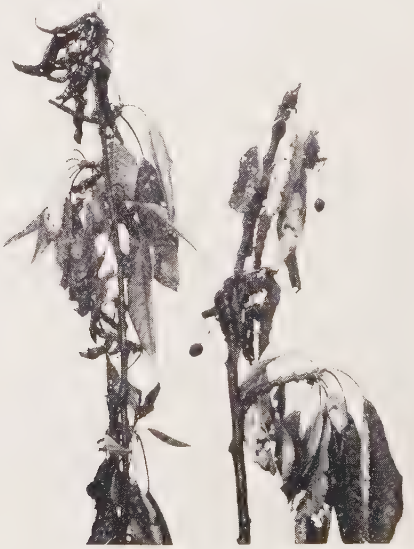


FIG. 6.

Spur wilt of cherry. Note brown and withered leaves on infected spurs (var. Early Rivers).

Abnormal features of the summer phase of the disease.

Normally only the leaves are involved in the summer phase, but in certain years the current shoot and spur growth may be attacked, resulting in localized lesions or even complete wilt of the infected part. Shoot wilt is rarely important. In 1949, however, it reached epidemic proportions on young apricots at East Malling and was considered the dominant phase of the disease. Individual shoots were attacked in so many places that severe defoliation resulted, and by the time the disease was checked by the onset of hot dry weather in June some trees had lost almost half of their leaves.

In spring, 1953, there was an exceptionally severe outbreak of leaf spot on cherry. Associated with this was a completely new form of the disease consisting of an attack on the young green spur tissues soon after the leaves were fully expanded (Fig. 5). Infected spurs frequently collapsed and the leaves turned brown and withered (Fig. 6). The infection then progressed into the older parts of the spur, sometimes as far as the branches to form 'summer' cankers. This spur wilt was widespread in the cherry orchards of Kent, particularly on the variety Early Rivers, where the effects on the immediate and future cropping were extremely serious.

Shoot and spur wilt are very closely associated with wet, cold, and humid conditions in the spring.

The effects of environmental conditions on the disease.

In addition to splashing the bacteria about the tree, rain also facilitates the actual entry of bacteria into the host tissues. Unlike many parasitic fungi, bacteria cannot actively penetrate the host surfaces and entrance usually takes place by conveyance in free water through wounds or through the pores on the leaves (stomata).

Experience over many years has shown that severe outbreaks of canker are usually related to abnormally wet conditions the previous autumn. The precise factors or combination of factors favouring spring infection of the leaves and shoots are not known, although it is clear that rain and low temperatures are important.

The mere concurrence of the various predisposing environmental factors is not in itself sufficient for epidemic infection. The host tissues must at the same time be in a suitable state for infection, i.e. the leaves immature and the shoots not hardened ; fortunately, such a combination of circumstances only rarely occurs. The unique outbreak of leaf spot and spur wilt on Early Rivers and Bedford Prolific in 1953 is an indication of what may happen when they do, unless active control measures are taken to check the disease.

How is the disease transmitted?

From the grower's point of view the most important problem here is the method by which the disease enters a young orchard in the first place ; this bears directly on the problem of establishing and maintaining an orchard free from the disease. The disease has been known to develop in orchards so located that chances of infection from outside sources, e.g. plum, cherry, and other *Prunus* hosts, were extremely remote. Further, in plantings near or adjacent to mature orchards where the disease is rife, the distribution of the disease usually bears little relationship to the source of outside infection. For these reasons it is believed that the disease is often brought into the orchard from the nursery. In some instances, e.g. where trees show obvious signs of leaf scar infections in the spring following planting, there is no doubt of this. Frequently, however, trees may appear healthy in the first year after planting and remain so for a few years and then suddenly develop severe symptoms. The explanation of this seems to be that the disease may be carried from the nursery and persist after planting in an orchard in a form in which it is not readily detected. In cherry, and perhaps in plum, the invisible or nearly invisible minute cankers under the leaf scars may be one way in which this happens. Alternatively it has been suggested that the bacterium can overwinter harmlessly on or near the surface of the buds and in this way is carried from the nursery, invading the leaves in spring and thus establishing the disease cycle. It has been shown experimentally that *Pseudomonas mors-prunorum* can in certain circumstances survive several months in this way, but to what extent it actually does this under field conditions is unknown.

Either of the above methods may also account for the original introduction of the bacterium into the nursery in cases where outside sources of infection are excluded. The scion material is most suspect, since rootstocks are on the whole more resistant. The amount of scion material used in budding or grafting, however, is so small comparatively, that introduction in this way is probably only very occasional. On the other hand conditions in the nursery are ideal for tree to tree spread so that more than one infected tree might conceivably result from one original focus of infection. Pending further information it is recommended that scion wood should be taken from selected healthy trees and be dipped in Bordeaux mixture before use.

Resistant varieties.

So far as is known all scion varieties of plum and cherry are *susceptible* to the disease, i.e. they will all take infection to a greater or lesser degree. As all fruit growers know, however, they vary considerably in their *resistance*. As examples of varieties of low resistance may be cited Napoleon cherry and Victoria plum, and of high resistance, Frogmore cherry and Purple Egg Plum.

In varieties of low resistance the bacterium makes more rapid progress through the bark tissues. Work on plum indicates that this may be partly due to the tendency in highly resistant varieties for the invading bacteria to be sealed off by a mechanical barrier at an early stage ; there is evidence also that resistance may have a chemical basis.

Varieties on the whole tend to be resistant to the leaf phase as well as to the canker phase. In cherry, for example, there is a general relationship between liability to canker and liability to leaf spot. Resistance in the leaf phase has an important bearing on canker infection. It has been found, for example, that approximately three times as many bacteria are present on the surface of leaves of Napoleon in autumn as on those of the more resistant variety Roundel. This difference, together with the fact that much higher concentrations of bacteria are required to start an infection in Roundel, accounts for relatively few infections occurring on this variety in the field as compared with Napoleon.

There is some evidence that certain rootstocks, e.g. Myrobalan B (plum) and F12/1 (cherry), may prove to be somewhat resistant to infection. This might be an important factor in control and is discussed later.

Control.

Details of the control measures at present recommended have been fully dealt with elsewhere (*Rep. E. Malling Res. Sta. for 1945*, pp. 134-7), and will, therefore, only be discussed here in general terms. Control can be tackled in two directions : (*a*) Horticultural practices, (*b*) Spraying with bactericides.

Horticultural practices.

Much of the trouble on plum, where stem cankers on young trees are the main problem, undoubtedly arises from the current practice of low working. In low resistance varieties, e.g. Victoria and Giant Prune, this results in the provision of a stem which is very liable to infection. Due partly to the tradition of high working on Mazzard (or Gaskin) stocks, most of which appear to be somewhat resistant, stem cankers are of less importance on cherry. The general adoption of high working in plum nurseries on the most resistant rootstock so far available, Myrobalan B, might well reduce the economic importance of Bacterial Canker on this host. Staddle-working, i.e. allowing the rootstock to form a head and separately budding or grafting the individual branches, provides a resistant crotch and is an added safeguard. This method might be particularly advantageous in cherry, where crotch cankers are so important.

The importance of avoiding wounds in the bark, particularly in the autumn, has already been emphasized. Whatever pruning is necessary should be done in the summer when wound infection is less likely. This applies also, of course, to Silver Leaf disease.

Spraying.

The principle underlying the spray schedules devised and tested at East Malling has been the control of *both* the leaf spot and canker phases of the disease. Sprays have been used, therefore, at two different times, in the spring or early summer to prevent leaf spot and in the autumn to prevent canker.

On cherry, home-made Bordeaux mixture, applied at 10-15-100 in mid-October, reduced canker considerably. The same material, applied at 6-9-100 in the spring (white bud) controlled the leaf spotting. From trials of this nature a very significant result emerged, i.e. that spring sprays *alone* provided some control of the canker phase. This underlines a point which has been continually stressed in this article, viz. the inter-relationship of the leaf spot and canker phases of the disease, and the importance of controlling leaf spot. The most effective control of cankers was obtained when spring and autumn sprays were used together.

A similar combination of sprays has proved less successful on plum. No clear evidence has yet been obtained that either spring or autumn sprays will control canker. Late spring and early summer sprays, however, effectively controlled leaf spot. It is at present recommended to spray plums with home-made Bordeaux mixture (4-6-100) about three weeks after petal-fall, and again two to three weeks later with a colloidal copper preparation diluted to contain 0·025 per cent metallic copper.

Bordeaux mixture for the later spray is inadvisable on older trees because of the persistent deposit it leaves on the fruit.

The reasons for the failure of autumn sprays on plum are not known. It may be perhaps that a different timing is required than for cherry. The whole question is at present being re-examined.

In commercial orchards the spray schedule for cherries is not always used to the best advantage. There are four main reasons for this :

Failure to spray trees when young.—Frequently control measures are not contemplated until trees are from 10 to 15 years old and beginning to show extensive signs of ‘ die-back ’. If the disease is allowed to develop to this stage the problem of control is enormously enhanced and it may be several years before the disease can be reduced to reasonable proportions. Probably much of this could have been avoided if the disease had been taken seriously at the outset and the trees sprayed from the nursery onwards.

Inadequate coverage.—In recent surveys of the number of bacteria on leaf surfaces in autumn, some of the trees being sampled became covered in Bordeaux mixture drift during the spraying of a row of mature trees only a few feet away. In some instances the coverage was considerable. This, however, had no apparent effect on the number of live bacteria on the leaves. By comparison the bacteria on the leaves of trees forming part of a spray trial at East Malling were effectively destroyed following complete and adequate cover by lance spraying. Abundant bacteria were found on unsprayed control trees on the same plot.

The above example illustrates the importance of coverage.

Late application of autumn sprays.—Sprays applied in late November or December are, so far as is known, of no value. Mid-October is probably the latest time for the autumn spray. There is evidence that a spray in the latter half of September, *additional* to the normal mid-October spray, may give enhanced control. This suggests that some infections take place earlier than mid-October, a conclusion also reached, it will be remembered, from leaf scar inoculation experiments.

Omission of spring sprays.—The importance of leaf spot in the disease cycle has already been sufficiently emphasized. Omission of spring sprays adds to the difficulty of controlling cankers. One spray at white bud must be regarded as a minimum. In certain years, possibly when environmental conditions favour *late* leaf infection, a petal-fall spray (Bordeaux mixture 4-6-100) gives added control. There is reason to believe that a petal-fall spray proved of value in controlling the epidemic spur wilt of 1953. Pending further information, therefore, its routine adoption is recommended as a possible safeguard against this form of the disease. A limited study of the possible use of injection techniques for the control of canker has been made at East Malling. It was thought that if certain substances were introduced into the sap shortly before leaf-fall they would make their way to the leaves and kill bacteria entering via the leaf scars. Results of experiments of this nature have been disappointing. The substances so far tried, although toxic to bacteria in test tubes, were ineffective when injected into the tree.

Summary.

Various aspects of Bacterial Canker, Leaf Spot and Shoot Wilt are discussed with particular emphasis on the disease cycle in relation to the formulation of control measures by spraying.

WILT-TOLERANT HOPS

By R. V. HARRIS

Keyworth's Midseason and Keyworth's Early.

A recently published report of the Institute of Brewing on large-scale brewing trials with the 1951 crop states that the two so-called ' Wilt resistant ' Wye varieties, Keyworth's Midseason (OR55) and Keyworth's Early (OJ47), are in general ' not favoured for dry hopping, but interest was found in them for copper use in blends of 25-30 per cent with conventional types '. Therefore, it is now certain that these varieties are not accepted by the brewers as equal substitutes for such Wilt-sensitive varieties as Fuggle, and that other and more acceptable varieties that stand up to Progressive Verticillium Wilt at least equally well are urgently needed in the affected south-eastern area. This is confirmed by recently published advice from the Hops Marketing Board that growers should not increase the present acreage under OR55 and OJ47.

Five promising new varieties on trial.

The first five candidate varieties for fulfilling this urgent need are Bramling Cross (OT48) bred by Professor Salmon at Wye College, the seedling 1147 released to the growers last year by Messrs. Whitbread, and seedlings C2, D1, and D3 bred by Dr. W. G. Keyworth at East Malling Research Station and not yet released to the growers and propagators pending further trial.

All these five varieties have given a good account of themselves in standing up to Progressive Verticillium Wilt in early cultural trials on a commercial scale, and in their recent first large-scale brewing trials by the Institute of Brewing, so that it seems probable that one, two, or even three of them may ultimately prove to be desirable substitutes for OR55 and OJ47, at least until further new varieties in this class from the long-term joint breeding project at Wye College and East Malling become available to the grower.

Availability of healthy planting stock.

Should this happen planting stock of Bramling Cross, free from Progressive Verticillium Wilt and therefore suitable for planting on Wilt-free land, should be available in bulk from specialist hop-propagators from 1955. With the other varieties, however, there must be some delay, for the limited stock of 1147 allocated through the Hops Marketing Board last winter was raised on Wilt-suspect land and can therefore be planted only on known Wilt-infected sites under licence from the Ministry of Agriculture and Fisheries. But work has been in hand at East Malling from 1953 to produce foundation stocks of this seedling and of seedlings C2, D1, and D3 (also raised on Wilt-suspect land) that are proved by rigorous tests to be free from the Progressive Wilt fungus and therefore suitable for planting on Wilt-free land. The earliest dates at which the progeny of such stock could be available in quantity for the grower are 1958 for 1147 and 1959 for seedlings C2, D1, and D3.

A policy for planting the new Wilt-tolerant varieties.

Now should one or more of these new varieties prove to be of outstanding merit, the question will arise whether the planting of such a variety could be safely encouraged anywhere in the hop growing areas. The answer to that question lies in the precise nature of the so-called ' Wilt resistance ' of these varieties. To be truly resistant to Progressive Wilt would imply a faculty for keeping the disease fungus outside in the soil which, if carried to its logical conclusion, would produce a variety immune to the disease, all the stock of which would be free from contamination and therefore safe to plant anywhere. But in fact we find that OR55 and the other new varieties mentioned above all tend to become infected with the disease fungus as do Fuggle and the other Progressive Wilt sensitive varieties, but differ from the latter in that such infection causes little or no wilting of the infected hill. The disease fungus in such varieties is thus more or less *tolerated* within the host plant, and hence the description ' Wilt-tolerant ' is now applied to them. One inescapable result of this is a tendency of such varieties not to immunity but to the condition of the *symptomless carrier*, examples and dangers of which are well known in other diseases, notably in virus diseases. Prospective growers of such varieties must therefore be warned that, although planted with Verticillium-free stock and continuing to look and crop quite normally, plantations of these varieties could well constitute in time a hidden source of infection for sensitive varieties in a neighbourhood previously free from the disease. A chance infection coming into a plantation of such a Wilt-tolerant variety on one or two sets, or by outside agencies, would be likely to escape detection until the disease had spread and was well established. Such a source of infection would, of course, be minor in intensity compared with infected sensitive varieties, but might well serve to start primary centres of infection in such varieties.

Within the concentrated Progressive Wilt area in the south-eastern counties such a risk would be slight compared to the already concentrated risk from other sources, and growers in this area can therefore use the Wilt-tolerants both to plant up already infected land, or to plant clean land as an insurance in the event of attack.

Outside this area, however, growers would be well advised to regard these varieties as a potential source of danger for the reasons given, and therefore not to plant them unless some of them come to be finally accepted by growers and brewers as the equals or superiors of the older Wilt-sensitive varieties and therefore good enough to replace them entirely.

Finally, it should be said that in our research on this character of Wilt-tolerance we are constantly on the look out for any clue to a lurking element of positive resistance which if ' bred up ' might lead to a Progressive Verticillium Immune, as distinct from a Carrier, type of variety.

Summary.

The prospects of five new seedling hop varieties as possibly improved substitutes for the extensively planted Wilt-tolerant Wye varieties Keyworth's Midseason and Keyworth's Early are discussed, and owing to the fact that the ascertained reaction of all these varieties to Progressive Wilt is one of tolerance rather than resistance, growers are advised not to plant them outside the Progressive Wilt area of the south-eastern counties.

IS CONCENTRATE SPRAYING WITH LIME-SULPHUR A PRACTICAL PROPOSITION?

By M. H. MOORE

By now many growers will have become accustomed to what seemed to be the fantastic notion that undiluted lime-sulphur could safely be applied to fruit trees. It is, nevertheless, a fact that has been established on small bush Cox trees in experiments ranging over the past seven seasons, and, more recently, on larger trees as well. But does it get us anywhere ? Is it one of those interesting things that it is well to know in case the information comes in useful one day, or can we really turn it to good account in routine pest and disease control—one of the most important and costly of all operations on the modern fruit farm ?

Time will show ; we cannot give an unconditional answer at present because we have not yet had enough opportunity to observe its large-scale merits under differing plantation conditions—and they are bound to play a very important part in arriving at the answer. Such limited experience as we have had shows that the notion is by no means as fantastic as it may appear, for encouraging results have been obtained on medium-sized to large trees with large-scale machines. In fact, given skilled application under reasonably good conditions for mist-blowing—conditions that, anyway, should be demanded for the best results even from ordinary hydraulic spraying—the method shows quite surprising promise.

Problems of a change in method.

Of course there are difficulties ; there always are. When hydraulic spraying became a thing of large volumes, high pressures, and multi-nozzle spray-brooms it was some little time before those who operated the lances got used to the change-over from a small spray-jet carried awkwardly at the end of a long lance. Consequently, the volumes of spray used per acre for a time showed great increases, and many plantations developed spray-damage symptoms. Similarly, if we now change over to small volumes of spray at greatly increased concentration, there will probably be a period of adaptation, during which there may be spray damage and uncertain control of pests and diseases. New techniques must be assimilated into the farm routine with due allowance for such hazards.

Experience has shown that the most likely cause of trouble is reluctance to forget much of what we have come to associate with successful hydraulic spraying—the forceful, drenching spray, dripping trees, and spray fluid in large quantities. First acquaintance with mist-blowing is apt to beget a mild shock of disappointment at the wispy look of the jets of fluid ; so also with the cover on the leaves. It is sometimes difficult to detect at first glance, but on closer inspection each leaf will be seen to have its fine coating, not as the film that we are used to, but as a collection of very small droplets, separated, but sitting close together. And it is important that they should remain separated if the spray is one of high concentration. There is no ‘ safety-valve ’ in mist-blowing ; in hydraulic spraying excess spray runs off the leaves—in mist-blowing, excess may be reached *before* run-off occurs with sprays of high concentration. When the droplets run together on the leaves—as they will before the drip stage is reached—slowly drying pools of concentrated spray are the result, and these may cause severe scorching, especially if they occur on the lower surfaces of the leaves. It is therefore important to remember that there is a limit to the volume of lime-sulphur concentrate that trees in leaf can safely tolerate. By and large, that limit is reached when the foliage has been given a uniform but close coverage of small, separated droplets. It follows that the smaller the droplets—within the limits of what the machine can economically produce and of what can be satisfactorily ‘ handled ’ under plantation conditions—the better the cover, and the less the likelihood of spray damage, provided the trees are not given too much in volume.

The value of intensive experiments.

This kind of basic information can be worked out satisfactorily on small trees using the deposit put on from an air-compressor and a paint-gun. By doing it this way not only can the effect of small variations in volume per acre and concentration of spray be more easily assessed under conditions that can be brought under reasonable control, but there is a great saving in land and trees. Nevertheless, the ultimate test is in the established plantation as a routine method of treatment, and it is this stage that will in time show its workability or otherwise as a practical proposition.

Results in 1953.

Further information was obtained last season from paint-gun work on the effective relationship between volume and concentration of lime-sulphur. This seems to be perhaps the most important of all considerations affecting whatever practice is ultimately adopted in the established plantation. For instance, how should we answer the obvious question : is it better to use a small volume of highly concentrated spray, or a larger volume of less concentrated spray ?—or even a small volume of dilute spray ? In other words, is it necessary to increase the concentration at all if we use a small volume ? If so, by how much ?

To throw some light on this, several concentrations (1, 3, 9, 27, and 81 per cent) of lime-sulphur were compared at a fixed and very small volume (3 galls. per acre), carefully worked out from an earlier trial as the right quantity of 100 per cent lime-sulphur to give safe and effective cover on these trees—established bush Cox's 5-7 ft. high on M.IX stock. Larger trees would, of course, need more volume per acre in proportion to their size and density for the same degree of cover. The control for this experiment was spraying to run-off with 1 per cent lime-sulphur pre- and post-blossom. Four applications of all treatments were made, two before and two after blossom, the last on 8th June.

Records made on the control of Apple Scab, Powdery Mildew, and Red Spider showed that the highest concentration was much the most effective, and resulted in least fruit-russeting. This russeting was evidently due to exposure of the fruits to weathering on trees with poor foliage, and not directly to the spray. Hence, the lower the strength of atomized lime-sulphur, the greater the russeting. There was no direct damage from any of the sprays. Spraying to run-off with 1 per cent lime-sulphur gave very broadly the same control as 27 per cent at this very small volume, and also, like the 81 per cent atomized, least fruit-russeting because the foliage was on the whole good, though scarcely as good as that receiving 81 per cent. Further experiments are planned to extend the number of differing concentrations compared. As far as we can judge from the figures so far available, 50, 81, and 100 per cent are likely to give similar results that will differ amongst themselves much less than from those given by much lower concentrations. Up to the present, where 50 per cent has been compared with 100 per cent, the 50 per cent has given the same degree of control when used at a moderate increase in volume per acre ; the two have not yet been compared at exactly equal volumes. It would be expected that, even in the high concentration range from 50 to 100 per cent, slightly better control would be given by the highest concentrations at equal volume per acre, because that much more sulphur would be deposited. The effective difference between 81 and 100 per cent would probably be very little. There is no practical virtue in choosing an odd figure like 81 per cent ; it happened to come in the range of concentrations chosen for experiment, where each one was three times that immediately below it.

The important point established by these experiments is this : with very-low-volume spraying, if the volume per acre is fixed at a level that is adequate and safe for 100 per cent lime-sulphur, the higher the concentration used, the better the results. But, to put matters in the right perspective, it must also be said that this kind of spraying, even at maximum concentration of fungicide, is unlikely to give much better results than *the same number* of normally diluted sprays thoroughly applied by hand ; the results of the experiments proved this. The advantages will lie in other directions, as reliance on lance spraying is becoming increasingly difficult on many farms. Nevertheless, the hydraulic method has always suffered one disadvantage that the concentrate method overcomes—that of the need to reduce the strength of lime-sulphur after blossom, which is responsible for some failures to achieve good control in a wet summer. There is no need to reduce the strength of the concentrate ; 100 or 50 per cent can be used before and after blossom, thus ensuring that there is a powerful and persistent deposit on the foliage to offset any tendency for Scab or Mildew to build up in mid-season from a few chance infections that have escaped the earlier sprays. Incidentally, these concentrations have exceptional eradicant action against existing scab-spots on foliage.

A choice of methods.

Better results with very-low-volume lime-sulphur sprays at the lower end of the concentration range could doubtless be achieved by increasing the number of applications and shortening the interval between them, but this increases operational costs. Similarly, improvement would be likely to follow an increase in the volume of spray used at moderate concentration, although with lime-sulphur this middle way seems to be the most risky. For example, about 50 gallons per acre of a 10 per cent concentration on medium-sized trees may give very severe damage because this volume, especially when dispersed in small droplets, is too much for the kind of deposit that ought to be given when using a caustic spray-concentrate. It may not be possible, especially before the trees are in full leaf, to fit in all the droplets and keep them separate ; they may run together as with ordinary spraying before the run-off stage is reached. The same volume dispersed in larger droplets may not give good enough cover at this concentration.

It is at present a moot point whether or not low-volume spraying is best achieved by fully automatic equipment or by an operator sitting at the back of the machine directing the spray. Much will probably depend on the chemical sprays chosen, and on their concentration. The second method should certainly be used with lime-sulphur of high concentration at very low volume in order to ensure good cover and absence of damage. It is important also with this concentrate that the foliage should be dry before spraying, otherwise the concentrate will be spread over the leaves in pools. The dilution brought about by the water already present on the leaves is the reverse of advantageous, for it gives rise to the ' moderately low volume, moderate concentration ' position referred to above. The fully automatic method is suitable for moderately low volumes of milder, non-caustic sprays at moderate concentrations, when the results may be quite satisfactory. It should be appreciated that these two approaches to low-volume spraying are very different ; it will be interesting to see how each fares in the exacting environment of farming economics. One thing is, however, certain—that any method will fail if it does not achieve good cover, for, with protective spraying, this is the essential basis of all first-class results.

We seem to be approaching a stage when the grower can be offered a variety of spray-methods for achieving a similar degree of control, and he can decide which of them is economically the most attractive for his circumstances. At this stage of experimental development we should avoid the temptation to think that there is one right way and all the rest are wrong. Is concentrate spraying with lime-sulphur a practical proposition ? The answer is probably yes, but the use of lime-sulphur as a concentrate is not necessarily a better proposition economically than some other method. It may be ; we shall see. The issue will depend to some extent on whether further experiments show that this method is applicable to insecticides as well as to fungicides ; it would be advantageous if possible to mix them together in the spray-tank for some of the sprays in the season's programme.

Summary.

Basic information from intensive experiments on the merits of lime-sulphur concentrate for Scab, Powdery Mildew, and Red Spider control on apple trees is discussed in relation to its likely impact on spraying methods on the fruit farm.

THE APPLE, PEAR, AND QUINCE APHIDS

By G. H. L. DICKER

Routine winter washing of apple and pear plantations has given such good control of aphids that growers have, in the main, ceased to regard these insects as serious pests of their orchard trees. Aphids are, however, still a potential menace, as the rapid rate of reproduction allows even a small population to increase to considerable proportions in a short time, either on the fruit tree during the spring months or on weeds during the summer. By returning to fruit in large numbers during the autumn these summer forms may then be responsible for high egg populations on the trees in the winter months. At the present time two further factors must also be considered ; the use of spring applications of DDT or BHC as an alternative to winter washes and the trend towards various forms of automatic spraying machinery. There is evidence to suggest that, in general, spring sprays will not give quite the same degree of control that we normally expect from winter washes. This results from two causes : firstly, the young aphids are partially protected by the opening fruit buds, and secondly, it has become a well-established practice to use less spray per acre when applying the spring fungicides than is considered necessary for a winter wash treatment. The young aphids, however, having found a bud from which to feed after hatching, are almost as immobile as the egg stage and control is therefore dependent on the direct contact action of the spray. Where spring treatments are applied for aphid control the same care in getting complete cover of the whole tree is as essential as when a winter wash is used.

With automatic spraying the cover is often still less complete than when hand lances are used, which in turn can account for such infestations as occur in orchards sprayed by this method.

As a result, minor aphid outbreaks may become more frequent even where modern spraying equipment is used. They will usually be confined to single trees, or even branches, and are unlikely materially to affect yields. At times, however, additional control measures will doubtless be considered by growers ; the object of this article is to provide a simple means whereby the common apple, pear, and quince species can be identified in the field and the risk of further injury be more easily assessed.

Identification.

All the aphids which commonly infest apple, pear, and quince can be identified quite easily by the colour of the wingless forms, the position of the infestation on the tree, i.e. whether spurs or young shoots are attacked, and the type of injury caused to the foliage. Occasionally a hand lens is necessary to study the colour pattern of the aphid. Fig. 1 illustrates the main characters of a wingless aphid,

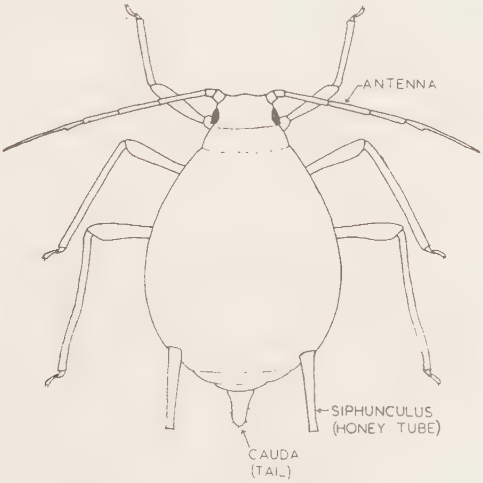


Fig. 1.

The main characters of a wingless aphid.

which, when alive, measures about one-sixteenth to one-twelfth of an inch in length. Arising from the head are a pair of slender antennae or feelers ; there are three pairs of legs, and the rear end of the body carries a short cauda or tail and a pair of siphunculi or honey tubes.

The first step in identification is to separate the aphids according to the general colour of the wingless forms. The green ones can then be identified by the characters given in Table I and the others either by their colour or by the type of injury caused to the foliage (Tables I and II). Only those species found most frequently are listed ; occasionally others, which do not agree with the following descriptions, will be found.

TABLE I.

CHARACTERS FOR IDENTIFICATION OF APPLE APHIDS.

Colour.		General description.
Green	(1)	Body uniformly coloured with black honey tubes and tail. Living in colonies at tips of young shoots, especially June-August. Causes leaf curling and sooty mould appears on leaves. **Green Apple Aphid** (*Aphis pomi* Deg.).
	(2)	Yellow-green with darker green stripes down the centre of the back and along each side. Short, pale green honey tubes. Living on spurs, under rosette leaves or among blossoms, until late May. **Oat-Apple Aphid** (*Rhopalosiphum insertum* Wlk.).
	(3)	A large aphid, with long legs, and feelers longer than body. Tail long, pointed, and pale green. At tips of young shoots, June-July. **Potato Aphid** (*Macrosiphum euphorbiae* Thos.).
Pink to slatey-blue		In green or yellowish curled leaves on spurs or young shoots, May-August. **Rosy Apple Aphid** (*Sappaphis mali* Ferr.).
Grey to slatey-blue		In red or yellow curled leaves of spurs and young shoots, May-July. **Rosy Leaf-curling Aphid** (*Sappaphis devecta* Wlk.).
Black		At tip of young shoots, June-July. **Black Bean Aphid** (*Aphis fabae* Scop.).
Dark brown and woolly		Colonies on bark of shoots, spurs or main framework. **Woolly Aphid** (*Eriosoma lanigerum* Hausm.).

Some variation in colour occurs among individuals in a single colony and between members of the same species at different times of the year ; the green species, for instance, may contain specimens varying from almost yellow to a fairly dark green. The identification of winged aphids is more difficult and has not been attempted here. It is wise to attempt to name only those wingless aphids that are present in colonies and obviously breeding on the host as, from time to time, individuals bred on other plants appear on fruit trees. This happens most frequently after a cultivation has been carried out, when aphids living on weeds may wander as their normal food plants begin to wilt.

Biological notes.

With the exception of the Potato Aphid and the Black Bean Aphid which occasionally infest fruit trees during the summer, and the woolly aphids, all the species mentioned overwinter as shiny black eggs on apple, pear, or quince. Hatching begins about the time the fruit buds are breaking and is generally complete by white bud on pear and green cluster on apple. These newly-hatched aphids cannot be identified as easily as the adults and so, in the following notes, there will be no reference to the early stages. In general, growers are not likely to be concerned with identification until breeding colonies are present, and these are inconspicuous until May. Any period mentioned in connection with injury thus refers to the time when colonies are obvious and does not necessarily include the full extent of the life cycle.

It should, perhaps, be pointed out that whilst the Green Apple Aphid, Oat-Apple Aphid, Potato Aphid and Black Bean Aphid are found on all three hosts, the other species live only on apple or pear, not on both these fruits. Older publications refer to the Rosy Apple Aphid attacking pear, but this is now known to be incorrect ; the closely related Pear-Bedstraw Aphid, with which it was formerly

TABLE II.

CHARACTERS FOR IDENTIFICATION OF PEAR AND QUINCE APHIDS.

Colour.	General description.
Green	*(1) **Green Apple Aphid** (*Aphis pomi* Deg.). *(2) **Oat-Apple Aphid** (*Rhopalosiphum insertum* Wlk.). *(3) **Potato Aphid** (*Macrosiphum euphorbiae* Thos.). See Table I for diagnostic characters.
Pink	In curled leaves on spurs and young shoots, May-July. **Pear-Bedstraw Aphid** (*Sappaphis pyri* Fonsc.).
Dark brown	(1) In reddish-green leaves folded along midrib. Only on spurs, April-May. **Pear-Coltsfoot Aphid** (*Anuraphis farfarae* Koch). **Pear-Hogweed Aphid** (*Anuraphis subterranea* Wlk.). (2) Small aphids curling leaves at tips of young shoots, May-August. **Brown Leaf-curling Pear Aphid** (*Longiunguis pyrarius* Pass.).
Black	At tips of young shoots, June-July. ***Black Bean Aphid** (*Aphis fabae* Scop.).
Dark brown and woolly	On roots or base of main stem. **Pear Woolly Aphid** (*Eriosoma lanuginosum* Hartig).

* These are the only aphids likely to be found on quince.

confused, is quite a distinct species. Thus, with the majority of species, there is no risk of cross infestation from apple to pear or vice versa.

Green Apple Aphid (*Aphis pomi* Deg.). Primarily a pest of young trees and nursery stock, the typical habitat of this aphid is the tips of young shoots where it lives on the undersides of the leaves, which become curled, and also along the stems. It can be recognized by its green colour, black honey tubes and dark brown or black tail. Also, it is the only green aphid occurring on apples and pears which is attended by ants. The eggs, laid on the bark of one-year shoots, are easily identified as other apple aphids choose the spurs or branches for egg laying.

Infestations arising directly from eggs will cause leaf curling in May, but the main trouble occurs in June and July when the tips of young shoots are colonized by winged aphids arriving from other sources, such as unsprayed apples and hawthorn. These migrants first produce nymphs on the unfolding leaves, then as the numbers increase the aphids also cluster along the apical portion of the shoot. Further winged aphids arise from these colonies and infest more young shoots. Unless destroyed by sprays or predatory insects the colonies persist throughout the summer and early autumn ; the shoots may be killed, and sooty moulds develop on leaves contaminated by honey dew.

Apple and quince are very susceptible to attack in the nursery ; young fruiting trees are also regularly attacked, but infestations on older trees are only severe in summers when favourable climatic conditions prolong the period of extension growth well into July. Hawthorn is one of the common wild hosts, but pear is seldom sufficiently infested to suffer injury.

Oat-Apple Aphid (*Rhopalosiphum insertum* Wlk.). This aphid can be recognized from the previous one by its distinctive colour pattern, being yellow-green with darker green stripes down the centre of the back and at each side. The honey tubes are short, pale green, and often edged with black at the extreme tips. It is usually found on the spurs, living beneath the rosette leaves which become slightly curled, or among the blossom buds. After hatching only two generations normally occur on fruit and, by the time apples are in blossom in mid-May, the earliest winged forms are migrating to grasses. Thus, if injury has not occurred by full bloom there is very little risk, as the population rapidly decreases due to migration of the winged aphids from their host-fruit.

Fruiting trees are most often attacked, apple, pear, and quince being host plants.

Potato Aphid (*Macrosiphum euphorbiae* Thos.). A very common aphid which occasionally infests the young growth of apple, pear, and quince during June and July. The aphids prefer to feed from the tender portions of the shoots rather than the leaves and, in addition to the typical green form, colonies often contain red-coloured specimens. It is larger than the two previous species, possessing long legs and honey tubes, and feelers longer than the body. The honey tubes are dark, except at the base, which may at first lead to confusion with the Green Apple Aphid, but it can be distinguished by having a long, pale green, pointed tail. The Potato Aphid is very easily disturbed, falling readily when an infested shoot is lightly tapped with the finger, and this habit taken together with the other characters should make identification fairly easy.

Infestations are started by winged forms arriving from potatoes or from the very large variety of weeds on which it normally lives, and only continue as long as the shoots are growing. It is seldom, if ever, of economic importance.

Rosy Apple Aphid (*Sappaphis mali* Ferr.). The individuals of a single colony often vary greatly in colour, from pink to slatey-blue. At first the spur leaves are infested and curled ; later the aphids attack the young shoots, causing leaf curl and stunting the growth. Unlike the Oat-Apple Aphid, this species continues breeding on apple as long as new growth is present, and so infestations may continue until July or even early August. The curled leaves often turn yellowish and then brown, but are never red as with the next species ; fruit from infested trusses remains small and distorted. From June onwards winged forms migrate to plantains where breeding continues throughout the summer. Only apple is attacked.

Rosy Leaf-curling Aphid (*Sappaphis devecta* Wlk.). Although the young nymphs may possess a pinkish tinge, the older ones and wingless adults are grey to slatey-blue with a fine white powdery covering. The main diagnostic character is the red and yellow colouration of the curled leaves ; also, infestations occur annually on the same small groups of trees and spread only slowly, as this aphid has no definite migrating stage. Field spread is due to wingless aphids walking from tree to tree. The life cycle is short, coming to an end in June or July when eggs are laid under bark of the main branches and trunk. Due to the sheltered position in which the egg is laid it is not possible to get satisfactory control with a winter wash.

Only apple is attacked ; infestations have been reported on Worcester Pearmain, Bramley's Seedling, Lane's Prince Albert, and Beauty of Bath ; Cox's Orange Pippin is not attacked by this species.

Black Bean Aphid (*Aphis fabae* Scop.). Colonies of this aphid, which can be immediately recognized by its dull black colour, occur from time to time during June and July at the tips of shoots of young trees and nursery stock. Infestations are started by winged aphids which migrate from other hosts such as spindle bushes or broad beans. At first the young leaves are attacked and curled, then the colonies extend along the shoot, stunting the growth and sometimes killing the growing point.

Apple, pear, and quince are attacked.

Woolly Aphid (*Eriosoma lanigerum* Hausm.). This aphid cannot be confused with others, as it lives in colonies on the shoots, branches, or trunk beneath a mass of wax strands commonly known as ' wool '. During the winter the adult aphids die, leaving only naked young nymphs which are mainly found in sheltered positions such as cracks, cankers, or under loose bark. These become active in March or April, when they begin secreting a fresh covering of wool, and adult wingless forms are present and breeding by the end of May. Winged aphids, produced during the summer, are responsible for a certain amount of spread, but this occurs mainly through the activity of the young nymphs of the summer generations which either walk to new sites or are carried, attached to fragments of wool, by air currents. Colonies are occasionally found on the main stem just below ground level and also on shallow roots disturbed by cultivation, but there is no evidence of a true root-living form in Great Britain.

Colonies examined in August and September may be heavily parasitized by a minute chalcid (*Aphelinus mali* Hald.). The affected aphids lose their wool and become a blue-black colour.

Pear-Bedstraw Aphid (*Sappaphis pyri* Fonsc.). This is the most injurious pear aphid, with habits very similar to the Rosy Apple Aphid. Curled leaves appear on the spurs during May, and soon afterwards the young shoots are attacked. Dense masses of mealy covered pink aphids live on the undersides of infested leaves and the foliage becomes sticky with honey dew. From small colonies in May the aphids rapidly infest entire trees and then spread to neighbouring ones. Winged forms occur from June onwards and migrate to bedstraw, but at the same time wingless ones continue breeding on pear and very heavy infestations continue until well into July. Only pear is attacked.

Pear-Coltsfoot Aphid (*Anuraphis farfarae* Koch) and **Pear-Hogweed Aphid** (*A. subterranea* Wlk.). The presence, during April and May, of red or reddish-green leaves arising from buds on the spurs provides a clear and simple means of recognizing these aphids. In addition to the very conspicuous coloration the leaves are folded along the midrib, so that the undersides meet, and are often twisted. Only leaves from vegetative buds on the spurs are attacked and, although the first two or three leaves to appear exhibit the typical symptoms, only one of each group is normally infested with aphids, which live between the folded portions.

Both species are very similar in habit and appearance, the adults of the first generation, or stem mothers, being large, round, dark brown aphids. They can, however, easily be separated in the field by observing the colour of the young nymphs of the second generation. Those of the Pear-Coltsfoot

Aphid are pale green whilst the Pear-Hogweed Aphid has brown nymphs. Only two generations occur on pear, the second becoming winged in May and migrating to coltsfoot or hogweed according to the species present. The entire life-cycle, from the time of hatching until winged forms appear, is passed on a single leaf, there is no secondary infestation of leaves and the damage caused is so slight that neither species can be considered of economic importance. Only pear is attacked.

Brown Leaf-curling Pear Aphid (*Longiunguis pyrarius* Pass.). This is a small aphid and easily recognized, as it is the only dark brown species living in colonies under curled leaves at the tips of young pear shoots. It is not a very common species and, when present, infestations are confined to a few scattered trees. The first sign of injury is noticed in May or June, and the infestation rapidly spreads to other young growth with aphids often present until August. From June onwards winged forms migrate to grasses. Only pear is attacked.

Pear Woolly Aphid (*Eriosoma lanuginosum* Hartig.). Very like the woolly aphid of apple in general appearance, but far less common and found only on the roots or at the base of the main stem of pear. The life cycle also differs as aphids migrate to elm in autumn where eggs are laid to form the overwintering stage. The spring generations on elm live in a sac-like gall formed from leaf tissue, which, when ripe, opens to allow the winged aphids to escape and migrate to the roots of pear. Winged aphids return to elm in the autumn to produce the sexual forms.

Summary.

Simple characters are tabulated and brief biological notes appended for the field identification of the common apple, pear, and quince aphids. These include the Green Apple Aphid (*Aphis pomi* Deg.), Oat-Apple Aphid (*Rhopalosiphum insertum* Wlk.), Potato Aphid (*Macrosiphum euphorbiae* Thos.), Rosy Apple Aphid (*Sappaphis mali* Ferr.), Rosy Leaf-curling Aphid (*Sappaphis devecta* Wlk.), Black Bean Aphid (*Aphis fabae* Scop.), Woolly Aphid (*Eriosoma lanigerum* Hausm.), Pear-Bedstraw Aphid (*Sappaphis pyri* Fonsc.), Pear-Coltsfoot Aphid (*Anuraphis farfarae* Koch), Pear-Hogweed Aphid (*A. subterranea* Wlk.), Brown Leaf-curling Pear Aphid (*Longiunguis pyrarius* Pass.), and the Pear Woolly Aphid (*Eriosoma lanuginosum* Hartig.).

SOME PREDACIOUS INSECTS OF COMMERCIAL ORCHARDS

By ELSIE COLLYER

Many species of predators feed on the Fruit Tree Red Spider Mite, and of this number only about half a dozen are found commonly in sprayed orchards.

The Black-kneed Capsid.

The Black-kneed Capsid (*Blepharidopterus angulatus* (Fall.)) occurs in many orchards and is often the most abundant predator. Many other members of this family are also predacious, although some, e.g. the Apple Capsid, are harmful. The Black-kneed Capsid can be distinguished from all the other species, both beneficial and harmful, by the presence in all its stages of black ' knees ' (Fig. 1). Winter is spent in the egg stage ; the egg is laid deep in the wood of the host plant, with only the white, oval egg cap showing on the surface. Egg-laying often causes a ' bump ' to form in the wood ; these ' bumps ' are small but distinct, and should not be confused with lenticels in the bark. Eggs hatch from May until mid-July, with the peak towards the end of June. The emerging nymph is little more than a millimetre in body length, and is yellow or pale green. The nymphs moult five times before becoming winged adults, all stages being very agile. The larger nymphs are green with an orange spot in the middle of the abdomen, and in the fifth stage they have dark developing wing buds. The nymphal stages occupy five or six weeks, so that adults begin to appear early in July, and may be seen as late as October. The chief egg-laying period is in August, and individual females lay up to 40 eggs each. The capsid passes through only one generation in a year, and therefore does not increase rapidly in response to favourable conditions. In addition to being predacious, this species is also partly plant-feeding.

Anthocorid bugs.

Half a dozen species of the family Anthocoridae occur on fruit trees, the two most common are *Anthocoris nemorum* (L.) which is four millimetres in length (Fig. 2), and *Orius majusculus* (Reut.) which is only two millimetres long. These predominantly black and brown insects are bugs, and like the capsids, have a long proboscis with which they pierce and suck their prey. They are entirely carnivorous in their feeding habits. They hibernate as adults through the winter, both in and around the orchard, and in autumn and spring suck many Fruit Tree Red Spider Mite winter eggs. Usually only females survive the winter ; they emerge in March and April and feed on mites, aphids, etc. The first eggs are laid in April and May. They are laid within the tissue of the leaves, on the under surface, with only the circular white egg cap protruding. The eggs hatch in about ten days into nymphs, and there are five nymphal instars. The *Anthocoris* nymphs are a dark reddish brown colour, and are very flattened ; the *Orius* nymphs are pale brown and far less conspicuous. By May the earliest nymphs are developing into adults, and two complete generations occur. Throughout the summer all stages are to be found occurring together. All stages are voracious feeders, and attack any available small living creatures, especially the inactive ones like red spider mites and aphids.

Stethorus punctillum (Wei.).

This is a tiny black ladybird, far less conspicuous than the larger black and orange species commonly seen feeding on aphids. *S. punctillum* is almost spherical, only $\frac{1}{25}$ inch in diameter, and if examined with a lens is seen to be covered with very fine yellow hairs. The life history is similar to that of the anthocorids, with two generations a year. It emerges from hibernation somewhat later, and is not usually found in orchards until late May or June. The immature stages are flat brown sluggish creatures that creep over the leaves amid the leaf hairs. There are three moults, and the final larval stage grows to about $\frac{1}{10}$ inch long before it pupates to form a black pupa, which hangs from the under surface of the leaf. The egg is pale yellow, and oval, and laid flat on the underside of the leaf. This species feeds in all stages solely on mites, and for survival needs a fairly plentiful food supply.

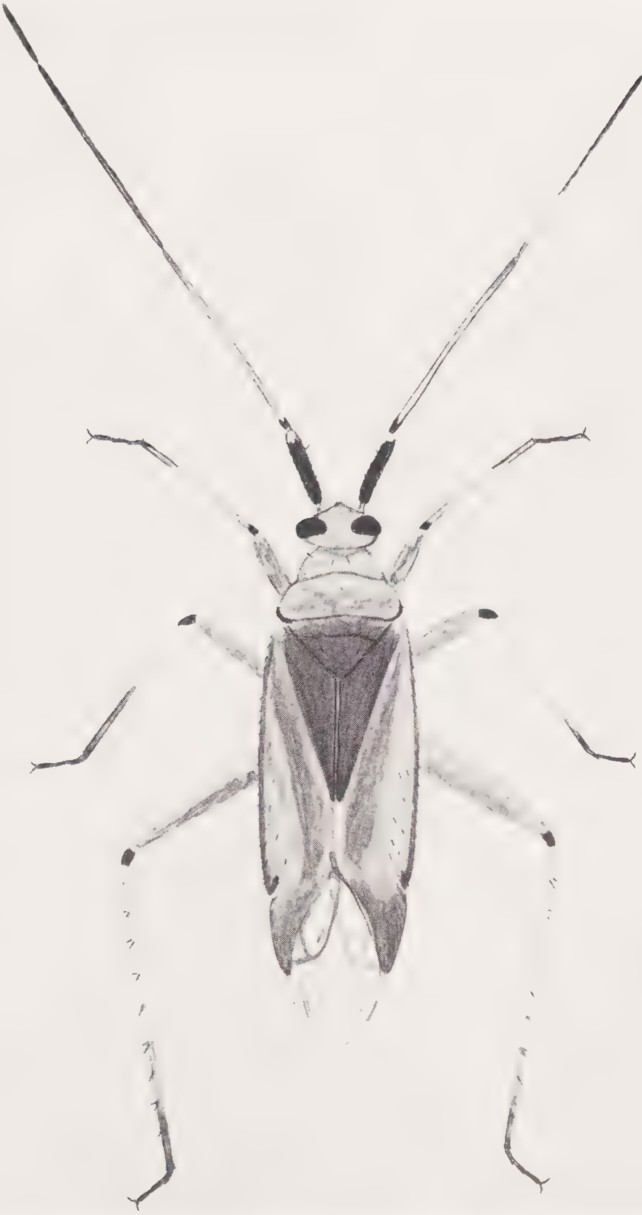


Fig. 1.

Adult Black-kneed Capsid. Female. × 16.

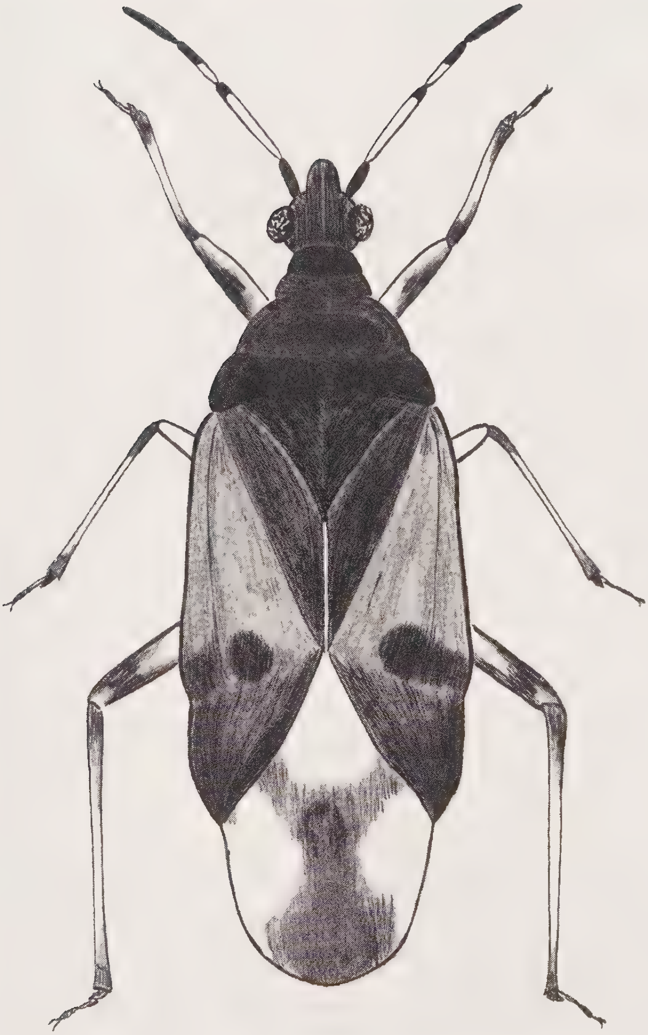


FIG. 2.

Adult *Anthocoris nemorum* (L). Female. × 25.

Coniopterygid Lacewing.

Of the lacewings the most important feeders on the Fruit Tree Red Spider Mite belong to the family Coniopterygidae. They are small inconspicuous insects, called ‘ dustywings ’ in America, and resemble winged aphids covered with a white waxy powder. The larvae are similar in habit to those of *Stethorus*, but are pink and white in colour and are somewhat more active. The ‘ dustywings ’ have two complete generations, and often a partial third, in a year; larvae can be found until December feeding on red spider mite winter eggs. These larvae spin white cocoons, about 4 mm. in diameter, on the trunks of the trees and spend the winter within. This species is less regular in occurrence than the other species described here. In some years, notably when there is a hot, dry summer, it becomes very abundant, but in other years it may be difficult to find.

Importance in Fruit Tree Red Spider Mite control.

When abundant the Black-kneed Capsid may reduce the Fruit Tree Red Spider Mite to a very low level. In some years it gives a commercial control, but does not do so in the same orchard for more than two, or at the most three, years in succession. Having only one generation a year it increases very slowly compared with the mites.

The anthocorids and *Stethorus* are usually scarce in the early part of the summer, becoming numerous later if the Fruit Tree Red Spider Mite is abundant. In some circumstances they do reduce mite numbers in June or July, but more usually they increase only late in the summer and begin to reduce mite populations in August, when damage has already occurred to the trees. These species are of importance in reducing autumn mite populations, and the subsequent numbers of winter eggs. The coniopterygid is abundant only when mite populations become high, but then it has considerable effect and in the autumn may suck up to 90 per cent of the mite winter eggs.

Effect of common spraying materials.

The routine winter washes tar oil and DNC-petroleum do not affect the overwintering eggs of the Black-kneed Capsid, and so it has remained abundant in commercial orchards while many other capsid species have become scarce. The winter washes do, however, kill many of the overwintering anthocorids, ladybirds and coniopterygid cocoons, which results in the relatively low numbers of these insects to be found in spring and early summer in most sprayed orchards.

Of the insecticides used in spring and summer many are toxic to these predators. DDT, BHC, parathion, and TEPP kill them all, and the first three have considerable residual toxicity. The predators differ in susceptibility to deposits of these insecticides ; generally speaking the capsid nymphs are most susceptible, the adult capsids and immature anthocorids are less so, while the adult anthocorids and all stages of the ladybirds are least affected.

The routine lime-sulphur applications, and also nicotine for Apple Sawfly, do not greatly affect these insect predators although a certain percentage, particularly of immature capsids, are killed. Derris has more effect on them, but has no residual effect, and does not give the complete kill so characteristic of the newer insecticides.

Summary.

A brief description and life history is given of the five predacious insects most abundant in commercial orchards : the Black-kneed Capsid, *Anthocoris nemorum* (L.), *Orius majusculus* (Reut.), *Stethorus punctillum* (Wei.) and a coniopterygid. The importance of these insects in Fruit Tree Red Spider Mite control and the effect on them of routine spray materials is discussed.

CULTURAL EXPERIMENTS WITH STRAWBERRIES

By DOROTHY J. WILSON

Recent cultural trials with strawberries at East Malling have been mainly concerned with planting systems, irrigation, and the treatment of the strawberry field after the crop is picked; and some general recommendations can now be made.

Spaced and matted planting systems.

Plants spaced at 18 inches in the row, with 36 inches between rows, and all their runners removed, have been compared with matted rows where runners were allowed to root along the rows to a width of 18 inches, and matted beds where runners were allowed to fill the space between two rows.

In the first experiments with Royal Sovereign the matted rows and beds cropped much more heavily than spaced plants. Yields of marketable fruit were 40-80 per cent higher from matted rows and up to 100 per cent higher from matted beds than from spaced plants. Even greater crop increases were obtained by limiting and spacing the runners within the matted systems at about 6 inches apart, but this was very laborious and is probably impracticable commercially in these days of expensive labour.

Huxley and Climax were then used in similar experiments. When runners were not limited in number, these two varieties produced very densely populated matted rows and beds. This was still true even when the number of original plants was reduced by half (i.e. 36 inches by 36 inches instead of 18 inches by 36 inches). In these very thick mats root competition for water was very acute and the amount of soil water available during the summer became the paramount limiting factor for yield.

When moisture was plentiful, matted beds of Huxley gave 75 per cent more marketable fruit than spaced plants (5¾ tons p.a. *v.* 3¼ tons p.a.). Matted rows gave 50 per cent more fruit than spaced plants. Matted rows and beds of Climax have given 20 per cent more marketable fruit than spaced plants (6 tons *v.* 5 tons). But this was only true when there was adequate moisture. In dry summers matted beds of both varieties have wilted severely, and matted rows to a less extent. The crop was then not only reduced in bulk but the fruits were sometimes so dull and flaccid as to be unmarketable.

In a few years this competition for limited moisture reduced fruit size, giving a smaller proportion of first grade fruit (⅞ inches diameter and over) from matted systems than from spaced plants, but in most cases the percentage of grade 1 fruit has not differed significantly between treatments. Only once has the proportion of rotten fruit been appreciably higher from the matted systems than from spaced plants.

On the whole, the wide matted bed is not to be recommended, not only because of its drought susceptibility but also because it has proved slow and difficult to pick thoroughly and difficult to keep free of perennial weeds.

The matted row, however, does appear to have distinct advantages. It can be satisfactorily made from plants set a yard apart in the row and the crop is still greater in almost all years than that from spaced plants 18 inches apart in the row. Fruit size rarely suffers with Royal Sovereign, though for Huxley and Climax a good summer water supply should be assured either naturally or by irrigation, or the crop increase is liable to be of small rather than large fruits.

Irrigation.

Fourteen irrigation trials have been carried out with strawberries. In four cases water was applied to matted beds and rows of Huxley or Climax that were already wilting, and, as might be expected, the improvement in the crop was striking. One inch of water increased the marketable crop of Huxley by 75 per cent in 1951.

In the other ten trials the water was given to plants not yet showing any signs of water shortage. Nevertheless, in every case the total crop was increased by irrigation.

Soil moisture tensiometers were installed on the plots in many trials, so enabling the drying out of the soil to be watched during the critical months of May and June. Water could then be applied at a known tension, to restore the soil block to field capacity or nearly so. More recently, soil moisture deficits have been calculated by the method described by Rogers and Goode (*Rep. E. Malling Res. Sta. for 1952* (1953), pp. 171-3) and water given to reduce the deficit by a known amount. The trials have varied considerably in detail, different amounts of water being applied in one or more doses on different dates, and of course the rainfall has varied from year to year. On one occasion when very heavy rainfall followed heavy irrigation, and another when humid atmospheric conditions prevailed in spite of a dry soil, the increase in crop was offset by an increase in rotten fruit and the marketable crop was slightly less or no more than that from unwatered plots. But usually the percentage increase in marketable fruit has been of the same order as the increase in total crop, sometimes reaching 30 or 35 per cent. Fruit size has usually also been improved so that a higher proportion of the crop came into grade 1.

It is therefore clear that benefit results from watering strawberries even before the plants wilt, and there is already evidence that the amount of crop increase may be correlated with soil moisture tension and calculated soil moisture deficits, though atmospheric humidity also appears to be important. Our experience so far indicates that watering is worth while if applied before the deficit reaches 3 inches, probably even at a deficit of 1 or 1½ inches. Alternatively, if a tensiometer is installed between 6 and 12 inches deep, watering when the tension reaches 20 cm. mercury is probably worth while. This tension is often reached after dry spells of 10 to 14 days in May or June.

How much water should be given ? If the soil moisture deficit is eliminated by filling the whole block occupied by strawberry roots to field capacity, any rainfall following shortly after irrigation is wasted by drainage. This is not, therefore, recommended. Considerable crop improvements have followed applications of ½ or 1 inch of water, and it is suggested that applications should be repeated as necessary to keep the deficit round about 1 inch. It is hoped to test routines of this type in ensuing experiments. But ½ inch of water should be regarded as the minimum useful quantity for a single application. Less than this will not penetrate dry soil far enough to reach many of the strawberry roots, and, in the dry weather when irrigation is useful, as much as $\frac{1}{10}$ inch of the water may be lost by direct evaporation from wet leaves and straw.

Burning and mowing strawberry fields after cropping.

The practice of setting fire to the straw and burning over strawberry fields after cropping is known to be a useful check to pests and fungus diseases, and four trials have now been completed to assess its effect on the plants themselves and their subsequent crops. It was compared with a standard treatment in which the straw and weeds were removed and runners cut off. This avoided any differential effect that might have resulted from cultivating-in the straw on unburnt plots. In two of the trials, mowing off the old leaves and removing them with the litter was included as a third treatment.

The first trial was with Royal Sovereign plants already three years old when they were burnt in July 1941. New leaves were visible within ten days of burning, and by May of the following year there was no apparent difference between burnt and control plants. The 1942 crop from the burnt plants was 22·4 per cent heavier than that of the controls. These crop figures and those of later trials in which plants of Huxley and Climax were burnt and Huxley plants mown, are given in Table I. In all cases, except Huxley in 1950, the succeeding crop from burnt plots was substantially greater than that of the control treatment. The exceptional case followed burning in the very dry summer of 1949 when the plants were severely wilted and a number of crowns were killed outright. That the crop in this case was not significantly lower than the controls must mean that the surviving crowns cropped more heavily than individual crowns in the plots which were not burnt.

In all three years when mowing was carried out the succeeding crop was also substantially greater than that of control plots, the increase being of the same order as that resulting from burning, except in 1950.

TABLE I.

MARKETABLE CROP, IN CWT. PER ACRE, AFTER BURNING OR CUTTING.

Trial.	Year.	Variety.	Control.	Cut.	Burnt.
1	1942	Royal Sovereign	24·9	—	30·5
2	1950	Huxley	72·6	88·6	71·5
	1951	Huxley	57·5	72·3	81·4
3	1951	Huxley	66·3	79·4	81·4
4	1952	Climax	68·5	—	77·8
	1953	Climax	98·2	—	126·3

These results demonstrate that, far from having a deleterious effect, burning over was actually beneficial in its effect on subsequent crops. It can be recommended whenever the weather is fine at the end of the strawberry harvest, except in excessively hot dry years. In such very dry seasons or when the weather is too wet for burning, then mowing or cutting the plants will give a very similar beneficial result, though it is rather more expensive to carry out.

Summary.

Planting systems, irrigation, and after-crop treatments for strawberries are discussed in the light of recent experiments.

FORTY YEARS' WORK AT EAST MALLING

By J. H. WALKER

When the station was founded in 1913 as the Wye College Fruit Experiment Station, the first Director, Mr. R. Wellington, defined its scope as ' the study of problems met with in the actual culture of fruit trees and bushes '. It consisted of some 23 acres of land, which experience has shown to have been very well chosen both for its uniformity and its suitability for fruitgrowing. When Wellington left on war service in 1914 R. G. Hatton took over, and from that time till he retired in 1948 the story of the station's progress is inextricably linked with his name. His election as a Fellow of the Royal Society and the knighthood conferred on him in 1949 marked the esteem in which his outstanding services to science and fruitgrowing are held.

Fruitgrowers, who had provided much of the impetus that led to the station's establishment, supplied the funds to provide and equip its first building, completed in July 1914. The nursery trade, quickly recognizing the value of the work after the issue in 1916 of Hatton's first report on the Paradise rootstocks, also made a grant to the station. Thus the station owed much to the fruitgrowing industry, especially over the lengthy period when but little support was received from official sources. It is also indebted to the enthusiastic and far-sighted chairmanship of Mr. Percy Manwaring (1919-1936), Mr. Spencer Mount (1936-1943) and Mr. Thomas Neame. Further help from fruitgrowers resulted in the purchase of an additional 40 acres, and the erection of the first fully-equipped laboratory and offices in 1921 ; the Ministry gave pound for pound on this capital expenditure and an increased maintenance grant on condition that the station became an independent research institute. This was effected by the formation of The Kent Incorporated Society for Promoting Experiments in Horticulture in the same year. Half the governing members of the society are nominated by scientific and administrative bodies, while half represent fruit and hop growing interests. Financial difficulties were, however, still considerable, and it is worth recording that in the early days the station's credit was personally guaranteed by two growers, and later by members of the Executive Committee.

Contacts made by the Director with research institutes and fruitgrowers abroad in the course of several extensive tours through all the important fruitgrowing areas of the Commonwealth, led to an active interchange of workers and to a steady stream of post-graduate students. The recognition of the station by the University of London in 1922 had made it possible for such students to work at East Malling, under approved teachers, for higher degrees.

The year 1926 saw the foundation of the Membership scheme that has played such an important part in the development of the station. Originally formed to support the station and to maintain on an ever-widening basis the contact between research worker and grower, it also enabled the members to obtain advice and surplus nursery material, privileges highly valued in days when organized advice on fruitgrowing was obtainable in but few counties and when commercial nursery material was often mixed and wrongly named. In addition to their regular subscriptions, the members have been largely responsible for finding the capital required for the purchase of land or the erection of buildings, culminating in the purchase and rehabilitation of the adjoining property of Bradbourne in 1938 at a cost of £30,000, of which the Ministry paid half. The property consisted of 200 acres of land not planted with fruit, and a large house, one of the finest examples of eighteenth century brickwork in Kent. The house was adapted to provide accommodation for the administrative staff, the Commonwealth Bureau of Horticulture and Plantation Crops, which had made its home at East Malling since 1929, and the combined library of the Bureau and the Research Station. The Bureau acts as a clearing house for horticultural information from all parts of the world through the medium of its quarterly periodical, *Horticultural Abstracts.*

In 1946, the Ministry accepted full financial responsibility for the Research Station, including the profit or loss incurred in running the experimental farm. Interested fruitgrowers still support the station in a wide variety of ways through their membership of the East Malling Research Station Association. Today, the functions of the Association have become more important than ever, for it is the focus of a wide variety of contacts between members and the expanding staff of the station, contacts whose importance to both grower and research worker need no emphasis.

In recent years some of the older plots that are no longer of experimental utility have been grubbed and new experimental plantations covering a considerable acreage have been planted, particularly on the Bradbourne land ; some of these are already yielding valuable information. It is unlikely that more than about 180 of the available 320 acres will be planted with fruit at any one time, most of the rest being in preparation for experimental use when required. The whole experimental farm is thus being run on a long-term rotation. The lowest part, being more susceptible to frost, is used for fruit propagation and nursery work.

The increase in scientific staff from 2 in 1913 to 133 in 1953, and the fact that no new laboratories had been built since 1930, had made very necessary the extra accommodation provided by the large extensions started in 1952 and to be completed in 1954. Their cost is being met in full by the Ministry of Agriculture.

The station has become widely known largely as a result of the collection and classification of the fruit tree rootstocks, the completion of which was Hatton's first task. Some of the original trees planted on these stocks in 1919/1920 are still under close observation at the station. Rootstock trials of apples, pears, plums, cherries, and peaches are still continuing and yielding valuable data. Many commercial rootstocks are not fully satisfactory, and for 25 years it has been the station's aim to produce better ones. Two series of apple stocks have been bred, and a full-scale trial of the most promising ones was planted on the Bradbourne land in the autumn of 1945. As the outcome of this long period of breeding and selection, five of the older of the two series have been selected for release in the United Kingdom, and are being multiplied as rapidly as possible to make them generally available. Four of these, being resistant to Woolly Aphid, are likely to be of special interest to overseas growers, and together with another ten rootstocks, also resistant to Woolly Aphid, they are being supplied to research stations overseas for testing as to their usefulness under local conditions. Anatomical studies that have made it possible to forecast probable vigour by examination of small pieces of root, have helped to speed up the work of selection. This technique may also prove useful in the search for stone fruit rootstocks with a wide range of vigour.

The importance of incompatibility at the union between stock and scion led to other anatomical studies that have shown that local disorganization occurs at the union. Practical methods have been worked out for overcoming certain types of incompatibility in the nursery by double-working with a suitable intermediate, and in the case of established orchard trees, by bridge grafts that reinforce and gradually replace the incompatible union ; in other cases choice of an alternative, but compatible, rootstock enables reliable trees to be raised.

A natural development of the detailed study of the fruit plant led to long and careful examination of the root system. Deep observation trenches with glass sides made it possible to observe the growth of roots with a binocular microscope and measure the rate of growth at different seasons, correlating this with measurements of soil moisture and temperature taken with specially designed instruments. Excavations and reconstructions of entire root systems made it clear that those of even dwarfing stocks extend widely and deeply. This investigation has recently been extended to the study of root systems from different soil types and under different systems of management.

Experiments on pruning began in the first year of the station's history and soon showed the importance of suiting the treatment to the variety, tree vigour, and purpose, and established the principles on which correct pruning treatments could be based. More recently planted pruning trials were designed to produce trees of different cropping performance suitable for studies in the control of biennial bearing. In the meantime the study of this problem on trees in older plantations has yielded valuable information. The effect of tree form and pruning on early cropping and the production of suitably spaced branches on young trees are also under investigation.

Much has been learnt about tree management since the early days of the station, and nowadays the main cultural problems of the experienced grower tend to be connected with soil management ; few aspects of the station's work arouse more interest. The early manuring experiments on the effect of nitrogen, phosphate, and potash yielded valuable information now incorporated into general practice. Following on from this and from the study of root growth and distribution, the effect of cover cropping and other cultural treatments upon soil structure and fertility and upon the mineral and water relations of the tree are now being intensively studied. In collaboration with the Ditton Laboratory of the Department of Scientific and Industrial Research nearby, an investigation of the effects of soil management and other field factors on the storage life and quality of apples is being actively developed.

The disastrous frost of 1935 brought the problem of spring frost damage to the fore. It was studied in a small way at first, to obtain information on the liability of sites to damaging frosts and the temperatures at which damage occurred ; since the construction in 1949 of special low temperature chambers in which frost could be simulated under controlled conditions, this work has been expanded. While investigations into the nature of frost damage and resistance are pushing ahead, a long-term breeding programme has been started with the object of raising late blossoming apple varieties of good market quality. Methods of protection from frost damage have also been considered ; of those tried so far, continuous water sprinkling appears to hold out most promise.

Varietal studies, no longer a major field of work at East Malling, are now undertaken by the

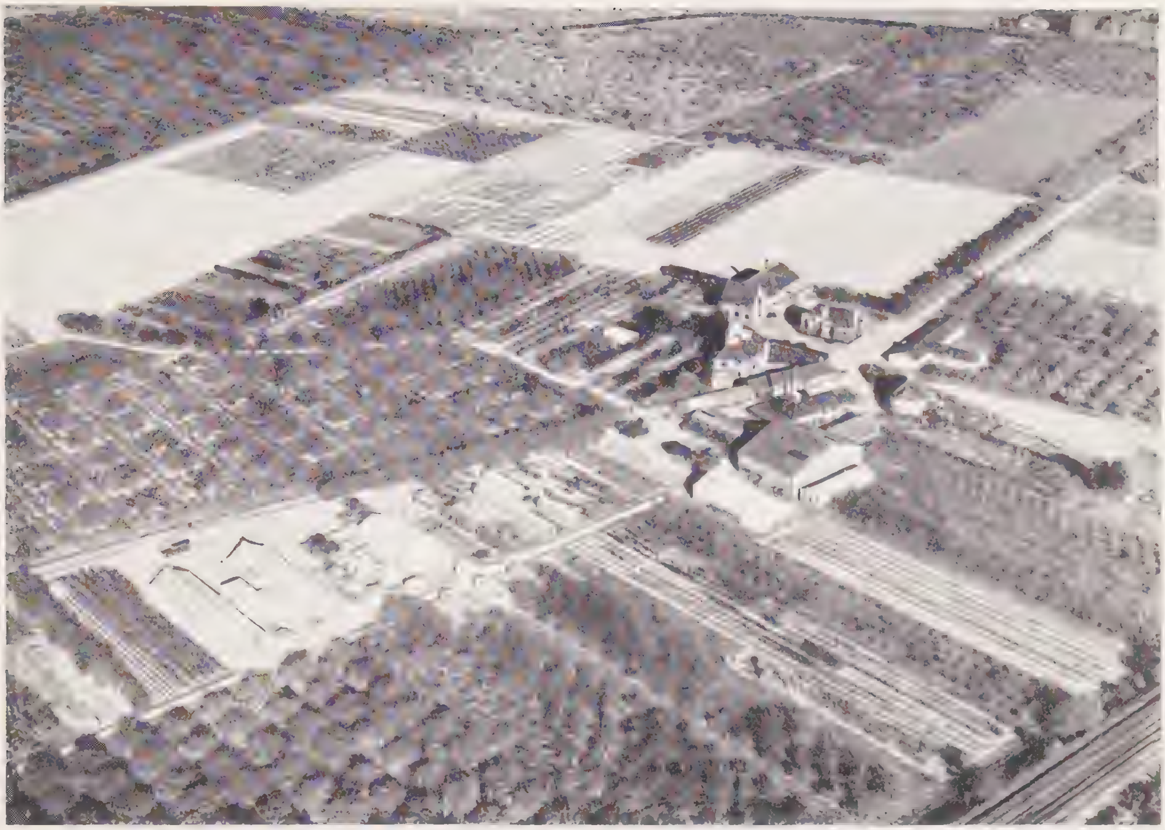


Fig. 1.

Aerial view of the laboratories, glasshouses, and neighbouring plantations taken in 1951 before the new building extensions. Part of Great East, the original field, is in the foreground.

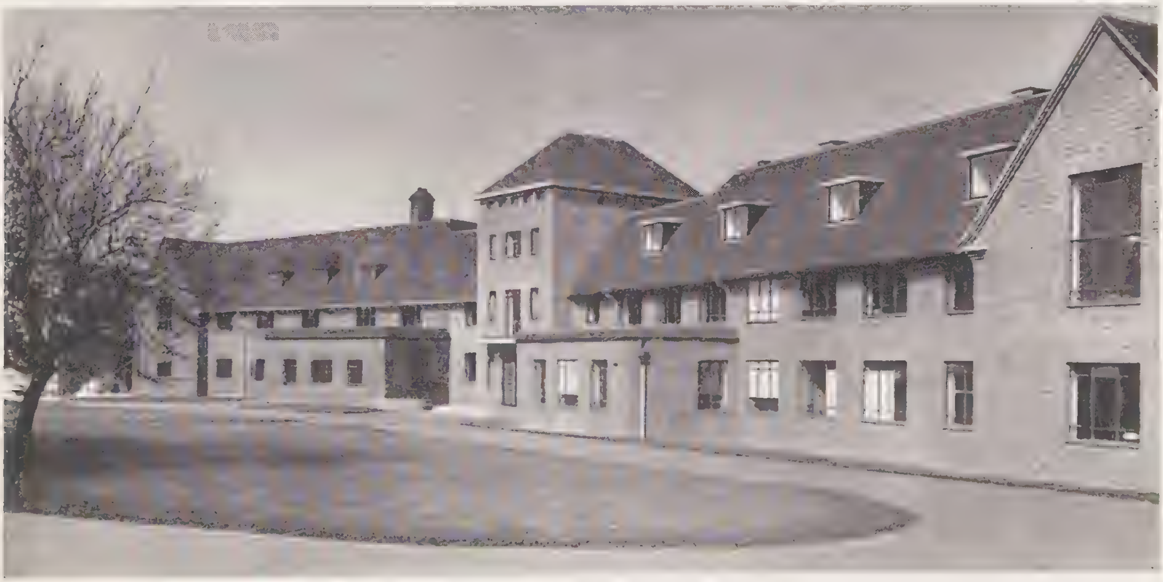


Fig. 2.

The E.M.B. building, showing the new tower and wing completed in 1953.

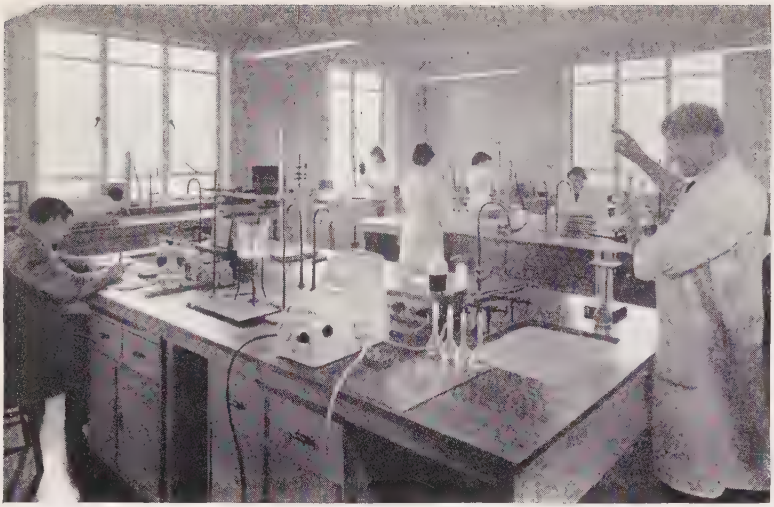


FIG. 3.

One of the new laboratories completed in 1953. This one is used by the Biochemistry Section for microchemical analysis of plant material.

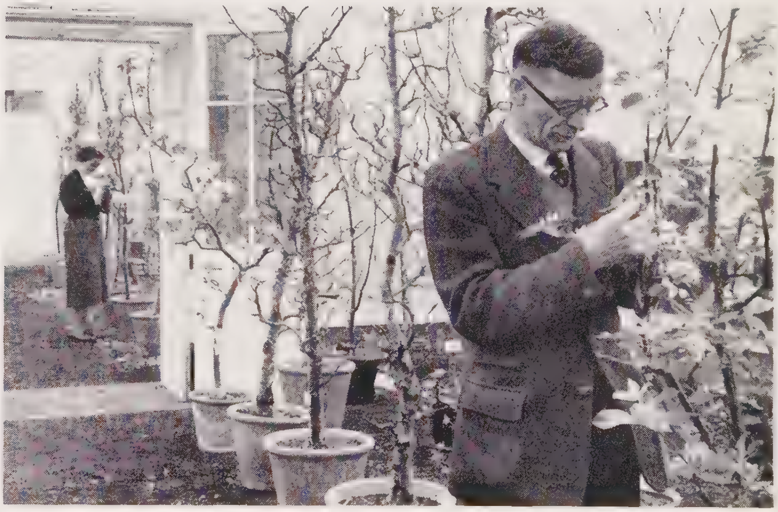


FIG. 4.

Pollinating apple blossoms in the insect-proof glasshouse used for plant breeding. Some 8,000 apple seedlings are being raised annually.

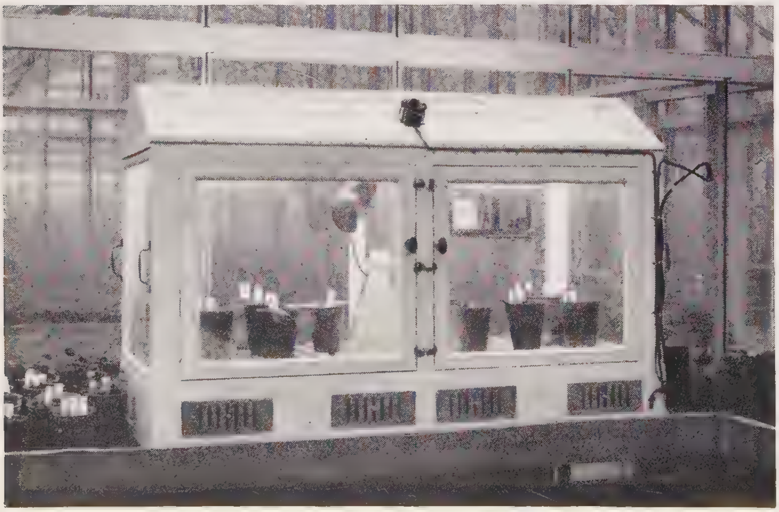
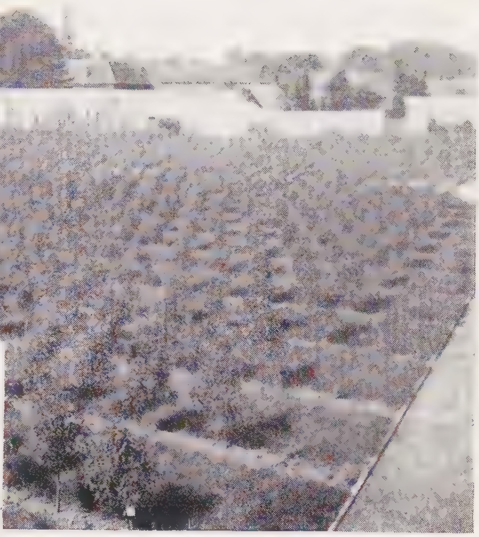
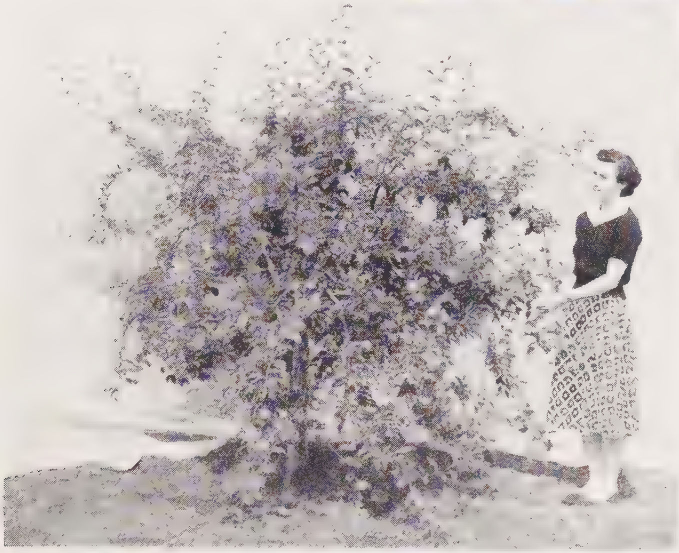


FIG. 5.

The frame used for heat inactivation of strawberry virus.

FIG. 6.
Right : The walled garden of Bradbourne House, planted with intensive fruit ; dwarf pyramids in the foreground.





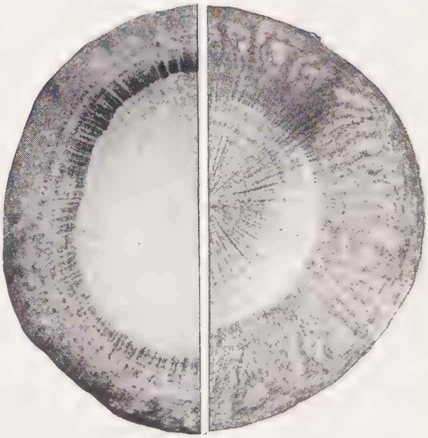


FIG. 7.
An eight-year-old Jonathan tree on MM.106, one of the new series of rootstocks resistant to Woolly Aphid. Its crops 1948-53 totalled 172 lb. *Right :* Such anatomical differences as those shown (M.XII and M.IX) have been used to forecast the probable behaviour of new rootstocks.

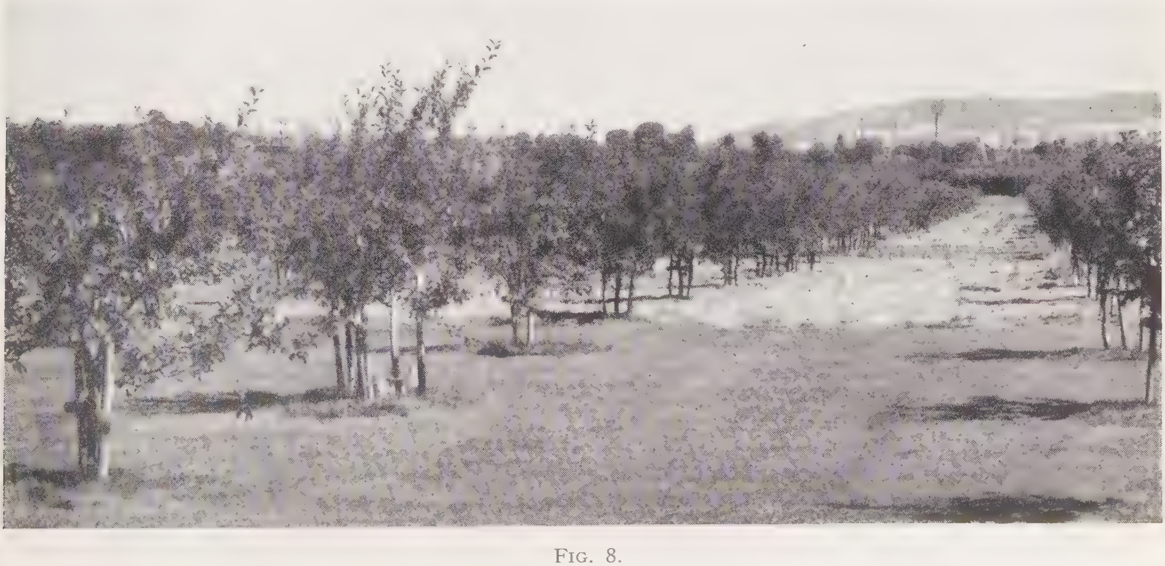


FIG. 8.
A view of one of the soil management trials planted on the Bradbourne land.

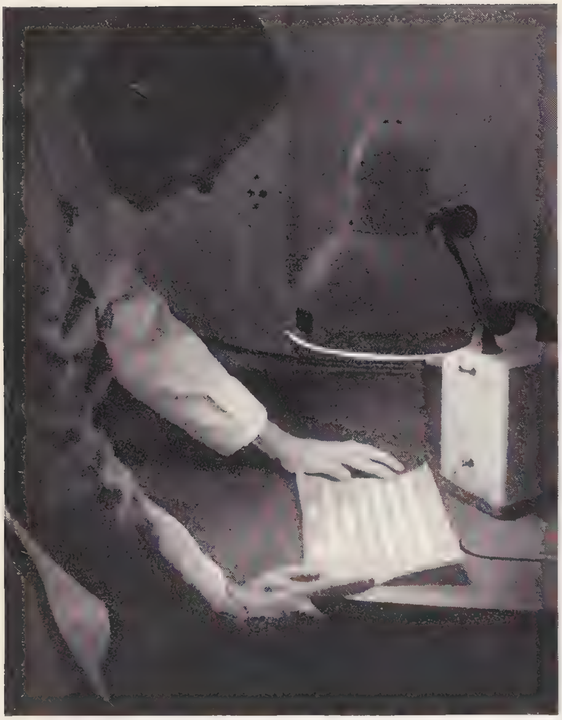


FIG. 9.

Examining a paper chromatogram under ultra-violet light.

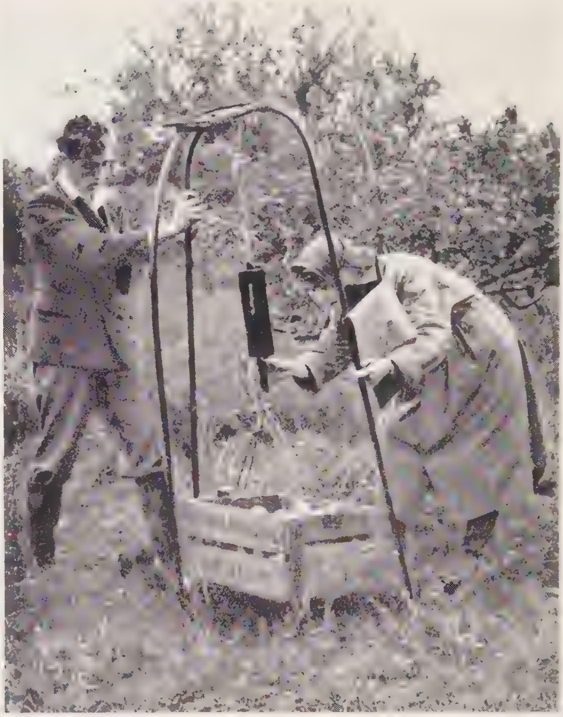


FIG. 10.

Workers weighing and recording crops in a manurial experiment.

FIG. 11.

The Director welcoming the visitors on a Members' Day.

National Fruit Trials ; varieties bred at the station are amongst those under trial. The best known are the Malling raspberries that now form a very high percentage of the commercial raspberry acreage ; more recently apple varieties have been released to extend the season of Worcester Pearmain and Cox s Orange Pippin. The black currant, Wellington XXX, was raised in the very early days of the station and has long established an important place for itself.

The central theme of the research programme from the beginning has been the study of the fruit plant and the biological and physical factors affecting its cultivation under orchard conditions. The incidence of these factors soon led to the original team of pomologists being augmented by various specialists—biologists, statisticians, and chemists—in order to ensure that problems were investigated from all aspects ; these specialists formed the nuclei of the eight sections in which the station is organized. The team spirit is still maintained, aided by regular but informal discussions between the scientific staff as a whole. Although the practical problems of the fruitgrower are always kept to the fore, the underlying fundamentals of the problems are investigated as the surest means of producing a satisfactory solution of enduring usefulness. The nature of the problems investigated has not only required the closest collaboration between individual research workers, but also with those at many other research institutes. Foremost amongst these must be mentioned the Research Institute of Plant Physiology of the Imperial College of Science, and for many years members of its staff have lived and worked in the Plant Physiology Section at East Malling.

The plant physiologist working in close touch with the propagator was able, by showing the importance of etiolation in layering, to increase the range of rootstocks that could be economically propagated. The partnership still flourishes in research on the propagation of rootstocks from hardwood cuttings, the wider use of which would offer important advantages. This work has shown that the condition and environment of the plant from which the cutting is taken may have more effect on its rooting than subsequent treatment. When these factors are favourable, the chances of success can be increased by the use of synthetic growth substances. The study of these is proceeding side by side with research into the occurrence and movement of those natural hormones and inhibitors that may affect root production in cuttings.

The physiology of rootstock effect is a fascinating problem to which a satisfactory solution is still being sought, and the reciprocal effects of stock and scion upon growth are being investigated with renewed impetus.

Work on the mineral relationships of the fruit plant has been the major preoccupation of the Biochemistry Section. Along with development of refinements in microchemical and spectrographic methods to meet the difficult analytical problems involved, a method of diagnostic plant injection was developed to help in the speedy assessment of the plant's response to additional supplies of elements that might be deficient. Of recent years the programme has been extended to include the study of the organic constituents of the fruit plant, particularly in relation to such problems as disease resistance and susceptibility, and the effect of mineral deficiency on the plant's metabolism ; this is already yielding valuable and interesting results. Close collaboration of biochemists with physiologists, pomologists, and pathologists will undoubtedly prove more and more necessary for the further solution of many problems and must play an increasingly important part in the work of the station.

All the major bacterial and fungal diseases of fruit plants and hops have been studied by the Plant Pathology Section. Particular attention has been paid to Apple and Pear Scab, Apple Canker, Brown Rot, Silver Leaf, Bacterial Canker of stone fruits, and Raspberry Cane Spot. The results of the work are apparent in the control measures widely in use today, but some are capable of further improvement and remain the subject of research. The development of spray techniques and control measures that will allow of reduction in the heavy cost of the spray programme is an important feature.

The study of virus diseases has been of increasing importance ; this has been facilitated by the erection of a large range of insect-proof, air-conditioned glasshouses. The black currant, strawberry, and raspberry growing industries were in turn imperilled by the spread of virus diseases, but the situation was saved by the introduction and propagation of virus-free clones, in collaboration with the Ministry of Agriculture whose officers are responsible for the inspection of plants under the various plant certification schemes. The combination of these efforts has been undoubtedly largely responsible for the improved cropping of strawberries, the crop per acre being almost double what it was in the decade before the war.

Until recently it was thought that our top fruits were relatively free from virus diseases, but orchard surveys revealed their incidence to be widespread, especially in plums and cherries. The problem is a particularly difficult one, as in some cases no definite symptoms are shown by infected trees. Testing is done by ' budding ' a range of seedlings with small chips of bark from infected trees ; if this is done in the spring, symptoms are usually expressed the same year. Little is yet known about the effect of virus infection on growth and productivity, and experiments have been initiated to investigate this problem.

The impact of the virus investigations on rootstock propagation has involved the large-scale testing of the station's clones of rootstocks, and their re-cloning as necessary. At the same time a collection of virus-free mother-trees for scion material is being built up. Already mother-trees of several important cherry varieties have been sent out to enable future propagation to be based on the working of virus-tested clonal rootstocks with virus-tested scion material.

Work on viruses naturally involves their insect vectors and entails close co-operation between entomologist and pathologist. Close study of the movement and control of aphids is being undertaken in this connection. Similar collaboration is involved in work on the association of Raspberry Cane Midge with Cane Blight, and of eelworms with bacterial pathogens in the Cauliflower disease of strawberries.

Studies of the Fruit Tree Red Spider Mite have been prominent in the programme of the Entomology Section in recent years, and since 1944 a special team has been working at a field station in Essex on the control of this pest. Work so far has given a clear picture of the mite in relation to its host and the effect of control measures upon it. More recently attention has been concentrated on the importance of natural predators and the effects of chemical control measures upon them, and on the search for an efficient and selective summer ovicide. The entomologists have likewise investigated the life histories of most of the other pests of fruit plants and evolved control measures for the important ones. Many of these pests have been virtually eliminated from the list of those that need cause real concern, allowing attention to be focused on perfecting the control of some of the more difficult ones.

The search for more efficient control measures led to the setting up of the Plant Protective Chemistry Section, and welded it into one team with the Plant Pathology and Entomology Sections. New and better chemicals are being sought, as well as improved methods for the use of those already employed ; in these studies special laboratory testing methods are constantly being elaborated to enable new chemicals to be accurately evaluated. Already several compounds have been developed and taken up commercially. As a corollary, an understanding of the fundamental causes of spray damage is being sought with the aid of the Research Institute of Plant Physiology.

The experimental plots of the station demonstrate the important developments during the past thirty years in the design of field experiments. This, together with the analysis of the figures obtained from the records taken, is in the hands of the Statistics Section. One of the guiding principles since the early days has been an insistence upon efficient design and adequate replication, often in advance of current scientific practice, even when this entailed accepting limitations on the scope of the research programme. The problems peculiar to experiments with perennial plants have been the subject of special study, while refinements in the design and interpretation of field and laboratory experiments have eventually increased the possible volume of investigation. The statisticians also help the research staff by suggesting short cuts that save time in recording results without loss of accuracy ; the importance of this may be gauged from the fact that some 27,000 trees are now under individual record. To this internal work must be added the design of fruit experiments being laid down by the National Agricultural Advisory Service on their Experimental Horticulture Stations, the National Fruit Trials, and commercial holdings.

An experiment at present being carried out by this section that may well have an important bearing on the station's future use of land is designed to investigate the possible effect of cultivation and management measures on the return to uniformity of the site of a grubbed orchard.

Although primarily designed to be of value to the commercial grower, the results of much of the work at East Malling are of great importance to the amateur fruitgrower. Use has been made of the old walled gardens at Bradbourne to demonstrate the benefit that can be derived, even in small gardens, from the application of these results.

The close association between fruit and hops on many Kent farms led to the latter finding a place in the research programme at East Malling. Earlier work was largely on the cultural side and on the selection and testing of disease resistant seedlings. Now the investigations are limited to pathology problems such as the serious soil-borne disease, Progressive Verticillium Wilt, and virus diseases ; cultural problems are studied by the Hop Research Department of Wye College.

The close link between the scientist and grower, so essential to the life of a research station such as East Malling, commenced with its very foundation, and has been fostered in two main ways. Firstly, by the publication of an Annual Report, sent free to members of the Association, which surveys the work of the experimental farm throughout the year, outlines the current research programme, and gives reports on experiments that have progressed sufficiently ; it also includes specially written popular accounts of results that are of practical interest to fruitgrowers, both commercial and amateur. Secondly, by organizing Members' Days, when the experiments in progress are shown to the growers.

Thus direct contact is maintained with a large section of the industry and the flourishing state of the Association gives evidence that the grower remains keenly interested. In addition to these days arranged specially for subscribing members, small parties and even individuals are able to visit by appointment and see those aspects of the work that specially interest them.

The National Agricultural Advisory Service was formed in 1946, at a time when the research programme was being reorganized after the war and its horticultural officers have relieved research workers of the burden of outside advisory work. The specialist fruit officer for the south-eastern province is stationed at East Malling, in close touch with our scientific liaison officers, while one-third of the country's horticultural officers visit the station annually for a two-day refresher course, as well as having other opportunities to see something of the work in progress. The close contacts and personal relations thus attained between the research workers and the advisory officers are of great value, both for ensuring that the latest research findings reach the growers with the least possible delay, and that the growers' problems are brought promptly to the notice of the research worker.

The maintenance of these and other links between the Research Station and other scientists at home and overseas, the advisory service, fruitgrowers, and the general public, is the function of the Scientific Liaison Section. At one time much general advisory correspondence on fruitgrowing problems was undertaken, but advice is now given to commercial growers by the officers of the National Agricultural Advisory Service, and to amateurs by the staffs of the Local Education Authorities.

Welcome visitors from overseas help to maintain contacts with research institutes in other countries, and this is furthered by the publication of research reports in the *Journal of Horticultural Science* as well as the Annual Report and specialist journals. The *Journal* is an official organ of Long Ashton and East Malling Research Stations, and has a world-wide circulation.

Summary.

An outline is given of the development and work of the Research Station from its formation in 1913 to the present day.

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